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USING MICROCOMPUTER-BASED LOGISTICS MODELS TO ENHANCE SUPPORTABILITY ASSESSMENT FOR THE USAF PRODUCTIVITY, RELIABILITY, AVAILABILITY AND MAINTAINABILITY (PRAM) PROGRAM OFFICE: A TAILORED APPROACH

THESIS

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AFIT/GLM/LSM/89S-40

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THESIS

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Preface

This study seeks to demonstrate the added value that microcomputer-based logistics support models can bring to the supportability analysis and decision making process. Microcomputer-based models promise greater flexibility and ease of use that can help a wide variety of Air Force managers quickly and more thoroughly assess the complex logistics support process.

While the ultimate writing task was mine, this research could not have been completed without the assistance of many people. I wish to thank my thesis advisor, Lt Col Robert Materna, for helping me to focus my research into a specific modeling area, as well as providing me with encouraging feedback. Additionally, I wish to thank both Capt Clinton Campbell and Mr Carroll Weidenhouse for their many practical suggestions, comments, and motivation. Without their valued assistance, this research would have been much more difficult. I'd also like to thank management and staff of the USAF PRAM Program Office for their generous assistance, understanding, and patience. Finally, I'd like to express my gratitude to my wife Jan, whose gentle understanding made the entire thesis process easier to bear.

David P. Martin

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List of Acronyms

AALPS: Automated Air Load Planning System

AAM: Aircraft Availability Model

AFIT: Air Force Institute of Technology

AFLC: Air Force Logistics Command

AFSC: Air Force Systems Command

ALC: Air Logistics Center

AOH: Annual Operating Hours

ASD: Aeronautical Systems Division

BMHC: Base Maintenance Manhour Cost

BMMC: Base Maintenance Material Cost

BMMH: Base Maintenance Manhours

BSC: Base Spares Cost

BSTK: Base Spares

CASA: Cost Analysis and Strategy Assessment

CNLV: Confidence Level

CSC: Condemnation Spares Cost

CSD: Constant Speed Drive

DLR: Depot Labor Rate

DMC: Depot Material Cost

DMH: Depot Maintenance Manhours

DMHC: Depot Maintenance Manhour Cost

DMMC: Depot Maintenance Material Cost

DMMH: Depot Maintenance Manhours

DOD: Department of Defense

DRC:	Dynamics Research Corporation
DSC:	Depot Spares Cost
DSTK:	Depot Spares
FHF:	Flying Hour Factor
IM:	Item Manager
IMCC:	Inventory Management Costs
ISTAP:	Information Systems Technology Application Program
JTIP:	Joint Technology Insertion Program
LAMP:	Logistics Assessment Methodology Program
LAWS:	Logistics Assessment Work Station
LCC:	Life Cycle Cost
LCCHPC:	Life Cycle Cost Analysis Program, version H for Personal Computers
LSA:	Logistics Support Analysis
LSC:	Logistics Support Cost
MODAS:	Maintenance and Operational Data Access System
MTBD:	Mean Time Between Demand
MTBF:	Mean Time Between Failure
MTBM:	Mean Time Between Maintenance
MTBR:	Mean Time Between Removal
MTTR:	Mean Time To Repair
NRTS:	No Repair This Station
O&S:	Operations and Support
PIUP:	Projected Inventory Usage Period
PMSH:	Peak Direct Maintenance Shop Manhours

PRAM: Productivity, Reliability, Availability, and Maintainability

PSC: Packing and Shipping Costs

QCS: Condemnation Spares

RAMDAS: Reliability and Maintainability Data Access System

R&D: Research and Development

ROI: Return on Investment

RST: Rapid Solidification Technology

RTS: Repairable This Station

R&M: Reliability and Maintainability

SCOPE-MOD: System Cost Operational Performance for Modification

SDTC: Second Destination Transportation Cost

SEC: Support Equipment Cost

SIDAC: Supportability Investment Decision Analysis Center

SILCC: Statistically Improved Life Cycle Cost

SPM: System Program Manager

SPO: System Program Office

SYSI: System Investment Cost

UC: Unit Cost

ULS: Useful Life Savings

VSCF: Variable Speed, Constant Frequency

Abstract

The purpose of this research was to demonstrate how microcomputer-based logistics models could be used to enhance the analysis of major project proposals for the USAF Productivity, Reliability, Availability, and Maintainability (PRAM) Program Office. The research used a tailored approach, assuming that the use of more than one model would be required.

The study starts by reviewing the importance of technology insertion to the military, focusing on the Air Force process. The evolution of the USAF Productivity, Reliability, Availability, and Maintainability (PRAM) Program Office is discussed. Included is the process that PRAM uses to assess technology insertion proposals. The bulk of the literature review discusses the evolution of computer-based logistics support models, focusing on the capabilities that current models offer the supportability analyst.

Three PRAM projects were selected for analyses. The projects represented "typical" projects undertaken by the PRAM office, which had been previously analyzed by the PRAM staff. Before any decision could be made about which models could be used to perform cost/benefit analysis, a structured approach was taken to determine the decision orientation and data available for each project.

An initial model survey was made to identify models that might have capabilities matching the level of analysis required for each project. The survey identified the need for a greater amount of data for all projects before any model could be used. During this additional data gathering process, several data quality issues surfaced, indicating the need for models with strong sensitivity analysis capabilities. After all additional data was collected, final model selection was made, and analyses were performed using two models, the Statistically Improved Life Cycle Cost (SILCC) and the Cost Analysis and Strategy Assessment (CASA) models.

This research demonstrated that more thorough economic analysis was possible using logistics models. In two of the projects analyzed, the findings revealed that the original PRAM analysis had overestimated the cost savings of the proposed improvement. Additionally, the models were used to perform detailed sensitivity analysis, thereby mitigating the effects of data uncertainty. The thesis concludes by recommending further work toward improving data quality, developing a standardized PRAM data collection process, accomplishing modeling implementation assessment, and conducting research in the feasibility of adopting the tailored modeling approach in other logistics support agencies.

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I. Introduction

General Issue

During the last quarter century, the pace of technological innovation has been staggering. Large organizations struggle to keep up with the explosion of innovative products and services. In today's complex technological environment, any organization that fails to seize the opportunities that technology offers often loses its strategic advantage over competing organizations.

Technological innovation is an extremely important issue for the military. While technological innovation is only one part of the overall military equation, when used properly it is "a significant discriminator on the modern battlefield," as well as a force multiplier (29:33). Failure of the military to transfer technological innovations from ideas, laboratories, or from the private sector into practical field applications may mean loss of strategic, tactical, and logistical advantages.

Technology insertion often offers the chance to reduce costs, while improving performance, reliability, and maintainability at the same time. This is true not only in new products and weapon systems, but for existing products and weapon systems as well.

Not all promising technological innovations can be successfully transferred into practical military applications, however. Before these innovations are adopted, they must meet military requirements. Within the Air Force today, before any proposed technology improvement can be implemented, it must be evaluated against Air Force supportability criteria as outlined in the USAF R&M 2000 [illegible]. These criteria include:

1. Increased combat capability.
2. Decreased vulnerability of the combat support structure.
3. Decreased mobility requirements per unit.
4. Decreased manpower requirements per unit of output.
5. Decreased costs (24:2).

Innovation decisions based on these criteria are often difficult to make. Much of the data on proposed technological improvements is very "soft" and therefore subject to qualitative analysis and subjective judgement. While these factors make up a very important part of any complete logistics analysis, most senior Air Force managers will not approve any monetary outlays for technology unless the costs and benefits of the investment can be quantitatively demonstrated. As much of this quantitative analysis is rudimentary, these managers usually welcome any efforts to improve their quantitative ability.

In the past, detailed quantitative analysis of the costs and benefits associated with technological innovations proved to be a demanding task due, in part, to the lack of portable, easy-to-use logistics support models that could help the analyst make sense of the massive amount of data. Many models existed on larger mainframe computers, and their restricted access and complexity often discouraged many support analysts from using them.

Today, however, advances in microcomputer technology have dramatically changed this process. Large increases in microcomputer memory, drastic reductions in the price of microcomputer hardware, and impressive improvements in microcomputer software have all contributed to the appearance of several microcomputer-based logistics support models that promise to greatly simplify the task of supportability assessment (40:39). Further improvements in this area offer the promise of even more logistics models in the very near future.

While the creators of these computerized logistics support models extol their virtues and promise assistance in supportability assessment, their arrival has spawned quite another dilemma. With all the logistics support models available today, how does an analyst know exactly which models to use? Additionally, how can the models practically assist in the quantitative analysis of proposed technological innovations?

A new initiative sponsored jointly by the Air Force Logistics Command (AFLC) and the Air Force System Command (AFSC) is trying to help analysts find answers to these questions. This initiative, if successful, would result in a permanent Supportability Investment Decision Analysis Center (SIDAC). The SIDAC is being challenged to:

> Improve and apply analysis methods, models, techniques, and enabling services for every aspect of weapon system supportability; and to proactively assess and promote enhancements to the [illegible] supportability investment [illegible].

Although the SIDAC [illegible] in the concept exploration phase [illegible] it will prove beneficial if it helps the [illegible] "wade through" the myriad of microcomputer [illegible] provide him or her with assistance in selecting those models which will facilitate the appropriate level of quantitative analysis.

Background

Within the Air Force, the Productivity, Reliability, Availability, and Maintainability (PRAM) Program Office is one of the Air Force's primary catalysts for technological innovation. PRAM had its roots in the 1972 HQ USAF "RIVET GYRO" project. The RIVET GYRO task force performed as an informal team whose objectives were to resolve operational effectiveness and support cost problems reported by any Air Force unit (14:1-1).

The RIVET GYRO task force continued to perform its mission until 1975 when it was directed to become a permanent organization by the Air Force Chief of Staff (14:1-1). It continued on with the same objectives of the RIVET GYRO task force, and existed as a separate agency until 1987, when it became part of the Air Force Logistics Command (AFLC)/Air Force System Command's (AFSC) Joint Technology Insertion Program (JTIP). The expanded mission of PRAM under JTIP is "to provide Air Force activities the means to immediately respond to new ideas to enhance combat effectiveness, improve productivity, and reduce operational and support costs" (14:1-1).

A major portion of PRAM's activities consists of evaluating these new ideas and technologies for adaptability to existing Air Force weapon systems. Projects proposed to PRAM can come from almost anywhere; from such diverse places as aircraft and item users, maintainers, or defense contractors (44).

All of the proposed projects are evaluated against Air Force supportability criteria, with the focus on improvements over existing systems. This evaluation process is currently being accomplished through a manual and highly qualitative validation process. Program managers evaluate project proposals based on the limited data presented in the proposal itself, personal experience in the area, and other qualitative methods, such as consulting with other AFLC and AFSC logistics and engineering personnel (17). While this process has proved practical, PRAM management would like to determine if and how current microcomputer-based logistical support models can be used to assist in the evaluation of supportability assessments for major PRAM project proposals.

Research Problem

This research was conducted to determine how the use of existing microcomputer-based logistics support models could improve the evaluation and validation of technology supportability assessment for major PRAM project proposals. Additionally, this study analyzed the benefits and the limitations of using a tailored modeling methodology for performing PRAM project proposal evaluation.

Assumptions

1. The state of microcomputer-based logistical support models has advanced to the point where a sufficiently large number of models are available for the Air Force to consider this problem valid.

2. PRAM project managers have sufficient knowledge of their proposed projects to provide satisfactory answers regarding the data required for the level of quantitative analysis undertaken.

Investigative Questions

To facilitate this research, each of the following questions was investigated:

1. How are proposals evaluated under the existing system?

   a. What types of decision orientations are typically considered when performing PRAM project analyses?

   b. What type of data collection procedures are used in gathering data to evaluate proposals?

2. What reliability, maintainability, supportability, and life cycle cost variables are appropriate for each proposal? Additionally, who determines the validity of these variables?

3. Are there validated microcomputer-based logistics models in existence for evaluating these measurements?

4. Do microcomputer-based logistics support models exist which can be adapted to specific PRAM proposal evaluations?

5. Can a tailored approach (the use of one or more models, or a combination of models) be used to assist in PRAM proposal validation across a wide spectrum of Air Force equipment and weapon systems?

6. What limitations exist in using current microcomputer-based logistics models in evaluating PRAM project proposals?

7. Can the use of current microcomputer-based, quantitative logistics models assist in the cost/benefit analysis of technology insertion?

Scope and Limitations

At any given period of time the PRAM Program office has more that 100 active projects under consideration. As this was exploratory research, in order to sufficiently narrow the scope of the research effort, only three project proposals were used for evaluation. According to PRAM personnel, these projects were typical of the range of proposals received by the PRAM office. Once the level of management analysis and data requirements were determined, each PRAM proposal was quantitatively analyzed using the model that best suited the analysis. While using more than one model for proposal analysis and then comparing results would greatly improve the internal validity of this research, it was beyond the exploratory nature of this study.

II. Literature Review

Overview and Scope

This review starts with the general issue of technology insertion, beginning with a broad overview of the issue, and ends with a discussion of specifically how the PRAM Program office adapts existing technologies to Air Force applications. Next, the use of microcomputer-based models as a means of quantitatively evaluating proposals for technology insertion within the Air Force is examined, starting with a discussion of the expanding use of these models and concluding with specific examples of their use. The final section of this review discusses current Air Force efforts to adopt a similar tailored methodology through the establishment of the Supportability Investment Decision Analysis Center (SIDAC).

The Importance of Technological Innovation

Few would argue the importance of the need for technological innovation in today's environment. Allesch, in his article about the innovation process and technology, remarked that because of the shortening of life cycles in technological development, innovation "has become a decisive factor for survival" in today's organizational world (1:3).

Because technology innovation is so vital, Allesch argues that innovation must be systematically managed and supported by top management within the organization.

Allesch states:

> The positive attitude of top management and executives towards innovation, and their support of those staff members directly involved in particular phases of the innovation process will decisively influence its success (1:5).

Allesch goes on to discuss how the innovation process should function within an organization, including five specific phases for successfully managing innovation: the recognition of opportunity; idea formulation; product definition; prototype solution; and finally, technology utilization and diffusion (1:12). While written for primarily a civilian industrial audience, this description of the innovation management process has broad implications for military organizations as well.

Muramatsu and Ichimura also discuss technological innovation, although their discussion is more narrowly focused on product innovation management (34:15). However, their article does address important aspects involved in managing product innovation. In their article, Muramatsu and Ichimura underscore the importance of product innovation management as an important business strategy. Their suggestion that product innovation management is critical to the fundamental survival of the corporation, also has implications for the military. While the military has no market share to gain or hold, it is very concerned with maintaining strategic advantage.

Muramatsu and Ichimura contend that any effective evaluation of product improvement management includes the use of specific measurements to gauge management progress. Although two of the measurements, the new product sales to total sales ratio and the profit gained by new product to total sales have no military equivalent, the concept of using return on investment (ROI) as a measure of management success is used in Air Force product innovation management (44).

The authors note the importance of developing information to help in the analysis of new product development. Product characteristics that should be evaluated during development include:

- specification
- efficiency
- reliability
- safety
- maintainability
- ease of operation
- transportability
- feeling
- guarantee
- life cycle costs
- others (34:21).

Muramatsu and Ichimura state that information gathered in each category "will help top management make decisions regarding new product development" (34:21).

It is important to note that with only a few minor modifications, the entire list of product characteristics applies to Air Force product innovation applications, as well as civilian applications. When Air Force product innovations proposals are evaluated, current Air Force regulations mandate that decision-makers consider the R&M 2000 goals of combat capability, combat support vulnerability, manpower, mobility, and costs when making innovation recommendations (24:2). These R&M 2000 goals incorporate all of the product characteristics that Muramatsu and Ichimura discuss in their article on product innovation management although they fail to mention any quantitative or qualitative measurement considerations for product characteristics (34:21).

Technological Innovation: Its Military Importance

While technological innovation has broad implications for survival across the organizational spectrum, nowhere is the successful management of technological innovations more keenly felt than in military organizations. Whereas the failure to successfully manage technological innovation in the corporate world might spell the demise of a particular corporation, failure to successfully manage technological innovation in a military organization can have a potentially severe impact on national security and war-making capability.

Retired Air Force Lieutenant Colonel David Mets highlighted the importance of technology on the battlefield (32:13). Mets implied that there have been times throughout history when technology was the decisive factor in battle.

He also suggests that there may have been times when a newly developed technology could have been the decisive factor, but military leaders were "simply not ready" to take advantage of the opportunity posed by technology, many times because they did not believe the technology would work (32:13).

Mets then points out several examples of where technology could have been the deciding factor, including advances during the civil war, the failure of military leaders to take advantage of the technological innovations of WW I, and a number of technological innovations in U.S. Air Force air superiority and close air support arenas that could prove to be the deciding factor on the battlefield of the future (32:16).

Unfortunately, Mets left out any discussion about the evaluation of technological innovation. However, Major Robert Maginnis, in his article "Selecting Emerging Technologies," gives us a brief expose on areas to evaluate when selecting technologies for battlefield use (29:33).

While Major Maginnis's discussion of evaluation criteria focuses in on emerging technologies for the Army, it also applies to existing technologies and cuts across service boundaries as well. Maginnis suggests that in testing each technology for its military application, the Army uses the following five questions:

1. Does the new technology allow the Army to do more with less?

2. Will it deliver more rounds on target, travel more miles per gallon, provide more punch per round, last longer between overhauls and more?

3. Does the new technology reduce the current administrative and logistical requirements of the system to be replaced?

4. Does the new technology simplify training?

5. Is the new technology the best use of scarce resources? (29:36-39).

Maginnis stresses the importance of selecting proper technologies for military applications when he declares:

> the U.S. and the U.S.S.R. are locked in a struggle to capitalize on military technologies. The objective is military superiority and political leverage. They are able adversaries we must counter (29:41).

Maginnis suggests that in order to counter the Soviet technological threat, the Army must integrate technological innovations into its weapons and equipment. He concludes by declaring that only by evaluating technological innovations against the five questions posed earlier in this article, will the Army encounter a measured amount of success with technological innovation (29:41).

Maginnis also discusses evaluation criteria for emerging technologies. In this regard, he narrows the focus of technological innovation even further than Mets, but focuses only on selecting emerging technologies for the Army. The methods which the Air Force uses to evaluate emerging and existing technological innovations for Air Force applications differ somewhat, according to its unique national security roles and missions. The next section of this literature review focuses on one office within the Air Force which finds itself intimately involved in the Air Force technological innovation process.

The USAF PRAM Program Office

The United States Air Force has a number of research and development programs dedicated to technological innovation. However, most of them are concerned only with developing emerging technologies for future weapon systems. For many years there was no coordinated effort to evaluate existing, "off-the-shelf" technological innovations for broad Air Force application. The Air Force lost many opportunities to take advantage of significant gains in technology (44). That changed in 1975, when the Air Force Chief of Staff established the Productivity, Reliability, Availability, and Maintainability (PRAM) Program. The PRAM Program was designated by the Chief of Staff to "immediately respond to new ideas to enhance combat effectiveness, improve productivity, and reduce Air Force operations and support (O&S) costs" (15:1).

The PRAM office accomplishes its objectives through the initial screening and thorough investigation of new ideas submitted to it from a wide variety of Air Force and private agencies. All of the ideas submitted to the PRAM office are proposals to incorporate new or existing technologies into fielded weapon systems or proposals to use this technology to improve an operational or support process (17).

The PRAM Program Management Directive directs the program office to identify projects with potential for improvement in:

a. R&M improvements which enhance warfighting capability and logistics performance.

b. Systems, subsystems, or equipment with consistently low reliability and maintainability and/or high O&S costs.

c. Maintenance, operating and training concepts.

d. Personnel productivity including training and skill levels.

e. Adaptability of equipment to broader applications.

f. Maintenance data collection systems, data information analysis systems, and other procedural systems (15:4).

If it becomes readily apparent from initial screening that the proposed idea will not improve one of the categories listed above, the idea has a very low probability of being evaluated by the PRAM office (44).

This initial screening is also called the PRAM investigation. It is designed to provide senior PRAM decision makers relevant answers to the following questions:

1. Is there a real problem that PRAM can realistically affect?

2. How critical is the problem? How does it relate to R&M 2000 objectives and the PRAM charter?

3. Is there a likely, practical solution? Are costs and schedule to attain the solution realistic?

4. Are there on-going related efforts? How are they related? Is there a potential duplication of effort?

5. If approved as a PRAM project, who will manage it? What other organizations need to participate?

6. Is there support from the operational command, the SPO or the SPM to perform this effort as a PRAM project?

7. Who will implement the results? How will they be implemented?

8. If a cost saving effort, can the "before" and "after" costs be obtained? Are the net benefits sufficiently large to justify the project? (14:3-1).

The initial PRAM investigation reflects the highly qualitative nature of these questions. As a result, the initial go-ahead decision relies heavily on the subjective judgement of senior PRAM management. The only objective of the PRAM office at this stage is to determine whether or not the idea has sufficient merit to justify the expenditure of resources in performing a full scale cost/benefit evaluation.

Once an idea has successfully survived this initial screening process, it becomes a Candidate Project. A Candidate Project "is a PRAM project proposal for which a project plan has been developed and all actions necessary to present that idea to the PRAM board have been accomplished and documented" (14:3-2).

The PRAM board is a group of Air Force managers who meet as necessary to approve or disapprove the expenditure of PRAM funds necessary to underwrite the research and/or development of Candidate Projects. For projects with research and development costs of under one million dollars, this board consists of senior JTIP and PRAM management. However, once the cost of R&D for the proposed project exceeds one million dollars, the Candidate Project must be approved or disapproved by a General Officer's Steering Group, consisting of General Officers from both AFLC and AFSC (15:3).

Assuming the appropriate board approves the Candidate Project for full scale testing and evaluation, it now becomes an active PRAM project. As most projects require contractor support, a procurement package is prepared by the appropriate PRAM project manager. Full scale testing and evaluation of the project then follows (44).

The successful testing of an active project normally ends PRAM's responsibility for the project, as PRAM's charter calls only for the research and development of any proposed idea, and they are expressly prohibited from spending any funds for project implementation. The ultimate implementation of any successfully demonstrated project rests with the using command (44).

While the PRAM board considers many factors in approving or disapproving a project, their decisions reflect the PRAM board's judgement of the potential for each Candidate Project to provide tangible benefits to the Air Force in terms of reliability, maintainability, supportability, and/or cost reduction. The decisions are made based on the information presented in the Project Manager's board briefing. If the Candidate Project does not show the potential for improvements in any of these areas, there is almost no chance for further development of the Candidate Project.

The determination of whether any Candidate PRAM project becomes an active project depends as much on the proper analysis and clarity of presentation of the Candidate Project to the PRAM board as the potential benefits of the project itself. Although the project manager for each Candidate Project must take many qualitative factors into account, at some point during the investigation estimates of benefits are quantified into some measure of merit.

For all PRAM Candidate projects the primary measure of merit is useful life savings (ULS), a quantitative estimate of the tangible cost savings to the Air Force over the useful life of the improved product or process (14:D-3). However, many other measures of merit, such as estimates of improved reliability, maintainability, and combat capability are often considered during the analysis of the Candidate Project and can directly impact the final decision of the PRAM board.

Although most of these estimates are presented to the PRAM board as quantitative estimates, usually in terms of ULS expressed as a dollar amount, they are arrived at by highly qualitative means. While this has proven practical, it has often left the project managers vulnerable to criticisms of incomplete analysis, although many project managers argue that proper analysis of Candidate Projects will always involve qualitative factors which can never be captured.

Indeed, many of the qualitative factors of the PRAM decision making process can never be captured using quantitative methods. It is also a fact that we live in a uncertain world, and performing cost/benefit analyses on products which have yet to be fully developed for military use is fraught with error and risk. But in spite of the uncertainty of any undertaking, there are a variety of methods used to attempt to quantitatively analyze the costs and benefits of projects.

Nevertheless, many PRAM project managers have been disinclined to apply quantitative methods to program analysis. The unfortunate result may be that decisions to approve or disapprove Candidate Projects may be based on inaccurate information, leading to improper allocation of scarce resources or missed opportunities for improved weapon systems or processes.

Most project managers within the PRAM program office would welcome any tool which would help them perform a better and more complete analysis of Candidate Projects. As the analysis of all Candidate Projects involves an assessment of costs and benefits, any tool which can provide the project manager with the opportunity to rigorously assess the benefits and perform sensitivity analyses may significantly reduce the risk of ultimate project failure.

Microcomputer-based Logistics Assessment Models: Analysis Tools

Project and program managers in the PRAM Program Office, as well as program managers throughout the Air Force, seek ever better ways to evaluate their programs and projects in an effort to make program and project decisions which assist in reaching Air Force reliability and maintainability (R&M) goals. While some ideas for PRAM projects have been so well thought out and presented that their overwhelming benefits became so immediately apparent that they did not require any in-depth analysis, most have been, and continue to be, fairly complex, requiring an analysis of trade offs between reliability, costs, manpower, mobility, and survivability (17). These decisions are often ill-structured and are ideal candidates for using logistics support models.

Blanchard discusses the integration of models with other techniques in the performance of logistics support analysis (LSA) (4:148). While his discussion of models and analytical techniques focuses primarily on more complex logistical analysis tasks than the supportability assessments required by the PRAM office, it provides a good insight into how models are used to perform such analyses.

Blanchard sees models as analytical tools that aid in problem solving. Additionally, models should facilitate the logistics support decision making process. Models are important, he argues, because they allow the analyst to consider alternative solutions to the problem being considered (4:148). Other benefits that he ascribes to the use of models in the LSA process include:

1. the ability of the model to integrate several individual elements of the LSA process into an entire system, thus allowing the analyst to uncover relationships between data elements that might otherwise go unnoticed;

2. the ability to "rapidly and efficiently" compare several different problem solutions;

3. the ability to define causal relationships . at previously went unexplained;

4. a fairly quick indication of data needed to use any given model;

5. the ability to make predictions, as well as evaluate "risk and uncertainty" (4:149).

For all the potential benefits posed by the use of models, however, Blanchard is quick to note that their use is not without limitations. First and foremost, he points out that models are only tools to aid the decision maker. They do not make decisions. He also points out that because of the unique nature of many logistical problems, the analyst may have to develop his or her own model in order to completely analyze the problem at hand. This, he says, is a difficult task, even under the most ideal circumstances (4:150).

An important problem in the use of any model is the amount and accuracy of the data used in the operation of the model. Unfortunately, while Blanchard does acknowledge the immense importance of this step in the successful use of any model, he does not elaborate at all on the severe consequences of using data that is inaccurate or untimely.

Blanchard's treatment of models was intended to cover both manual and computer-based models. Additionally, he provides an introduction to four categories of problems, in the area of logistics, that computer-based models were intended to help solve. According to Blanchard, these categories include:

1. Conceptual design and advanced system development.

2. Detail equipment design.

3. Determination of specific logistical support requirements.

4. Assessment of logistics support effectiveness (4:438-439).

While discussing specific computer-based logistics support models, Blanchard elaborates on earlier cautions of model use. This time, however, his specific focus is on the pitfalls and abuses of computer-based models. He warns the analyst against attempting to use an "all-inclusive" model, recommending that the analyst use an "integrated set" of models instead (4:441). Blanchard sees the use of an integrated set of models as a clearly superior approach, because it provides the analyst the flexibility to solve a wide variety of problems. However, in his enthusiasm for this integrated approach, he fails to address the problems of additional training and the difficulty of model maintenance that such an approach brings to the LSA process.

Blanchard also warns against the potential danger of "gross oversimplification" of the problem through the use of computer-based models. While the model may be "mathematically feasible," it may not be an accurate reflection of reality. The end result might be a model which does not provide the analyst or decision maker with any useful results (4:441).

The last caution Blanchard makes regarding these computer-based models is against becoming too attached to any one specific model. He argues that there is a tendency for analysts to become "so attached" to a specific model that "they will insist that the model is the real world and/or is directly applicable to all problems at hand" (4:442). Blanchard again warns that models are "only a tool" for assistance in the decision making process "and cannot be considered a substitute for experience and judgement" (4:442).

Blanchard finishes his discussion on computer-based models by giving only a couple of examples of models that exist for problems falling into logistics support or assessment categories. While he briefly describes what each model accomplishes, he does not attempt to explain the relative merits of any of the computer-based models, nor does he give the reader many clues as to the complexity of some of the models.

Drezner and Hillestad also discuss models and their use in analyzing logistics supportability. Their treatment of this area was more specific than Blanchard's, with their focus being on a broad review and analysis of the roles that models have in solving logistics support problems. Additionally, they discuss future trends in the area of logistics models (16:1).

As Figure 1 illustrates, Drezner and Hillestad argue that a logistics model is a combination of methodologies and measurements as they apply to one or more functional areas of logistics support (16:4). This combination of methodologies and measurements can be as simple as a single application of a methodology and measurement to one functional logistics area. However, as weapon systems become more technologically complex, more often a logistical model becomes an integrated set of methodologies and measurements being applied to a cross functional set of logistics support areas (16:4-5).

FUNCTIONAL AREA

* Maintenance
* Supply/Inventory
* Transportation
* Communication
* Other (procurement, basing, facility location and layout, etc.)

METHODOLOGY

* Simulation
* Mathematical programming
* Network methods
* Decision methods
* Statistical and probability methods
* Other (heuristics, production functions, etc.)

THE LOGISTICS MODEL

MEASURE FUNCTIONS

* Individual function measures--e.g., fill rate, equipment utilization
* Cross functional peacetime measures--e.g., operational ready rates
* Cross functional wartime capability measures--e.g., combat capable aircraft available to fly as a function of time

Figure 1. The Logistics Model(16:4)

Drezner and Hillestad discuss the various ways models have developed and have been used in each of the functional areas. In doing so, they raise many fundamental issues of the use of models in the logistics support arena, and suggest several areas of improvement. They are concerned that most models focus too narrowly on a single functional logistics area, and fail to capture appropriate relationships that may occur between functional areas. They also raise concerns about the type of mathematical, statistical, and probability assumptions that are often carelessly generated during model development. They point out that most models built for logistics support assume that much knowledge exists concerning various expected values and probability distributions occurring in logistics data, when in fact very little is known about many of these data probability distributions (16:13).

Probably the most important issue brought out concerning logistics models, however, is their peacetime-wartime dichotomy. According to Drezner and Hillestad, the combined effects of a "long period of peacetime activity for the military, the reduction in real defense appropriations, and the increasing cost of sophisticated weapon systems" resulted in the development of a host of models with emphasis on "peacetime efficiency" (16:17). This emphasis on peacetime support objectives and peacetime efficiency, however, conflicts with the more dynamic logistical support requirements that almost certainly will occur in war. Drezner and Hillestad claim that much more emphasis is needed in developing models which will account for the logistical support requirements needed for a variety of tactical wartime scenarios (16:18).

While developing models that include combat capability measures of merit is indeed a very important task for future logistics model developers, the simple fact remains that budget constraints and economic benefits remain important parts of any good analysis. However, Drezner and Hillestad devote only a small portion of their article to discussing the economic aspects of logistics models.

This analysis of logistics models assumes that the reader knows that most of the models and modeling techniques discussed require the use of computers to provide the analyst with any concrete benefit. Nowhere in their entire discussion of logistics models do they mention the need to use computers to run most of the logistics models currently in use.

Another issue that Drezner and Hillestad do not spend very much time discussing is the use that many logistics support models make of dollar costs in performing analysis. Many of the newer logistics support models use important measures of merit other than cost. While these newer measures or merit (reliability, maintainability, and combat capability) are extremely important in the supportability decision making process, the fact remains that, especially in today's budgetary environment, many senior Air Force managers are interested in relating reliability, maintainability, combat readiness and mobility measures of merit into bottom line cost figures. This is especially true in the PRAM program office, where currently one of the most important quantitative measures used in evaluating any project is the useful life savings the project is expected to accrue and comparing that to the initial investment that the PRAM office will have to make in developing the military application of the technology.

The PRAM Program Office calls this ratio of useful life savings to investment costs the return on investment (ROI) accrued by the project. Although this definition of ROI is unconventional (traditionally ROI is defined as the monetary return a business firm in the private sector receives in return for its initial dollar investment, expressed as an annual percentage rate), it adequately expresses the idea of logistics analysis performed in terms of economic costs and benefits.

PRAM's trade off analysis, comparing up front investment costs against projected savings in operational and support costs over the useful life of a project, is not a new idea. For over fifteen years the Air Force, as well as the entire Department of Defense, has been concerned with performing trade off analyses of weapon system acquisition costs of against their operational and support costs.

This concept is now commonly referred to as life cycle cost analysis. Very broadly defined, it "refers to all costs associated with the system and or product and applied to the defined life cycle" (3:9). Within the Air Force, the categories of life cycle costs include research and development costs, investment costs, and operating and support costs (31:11).

Many logistics support models have been developed in recent years that attempt to perform various aspects of life cycle cost analysis. In 1978, Marks, Massey, and Bradley performed an in-depth evaluation of several of the more commonly used life cycle costs models in an effort to help acquisition managers contend with the uncertainty involved in the newly emerging field of life cycle cost analysis (31:v). While this report (referred to as the Rand report) primarily focuses on how the various life cycle cost models are used in the acquisition community at large, the observations, conclusions, and recommendations of the Rand report are very salient to any serious review of logistics models.

The Rand report was important because it reported findings concerning problems with both the life cycle costs process and life cycle cost models. Unfortunately, it discussed data collection problems for these models only briefly, failing to address the consequences of collecting poor data.

Although the Rand report was motivated by concerns of how aircraft configuration changes and modification proposals for systems were evaluated in light of development, investment, and operational and support costs, it soon turned into a systematic evaluation of the entire life cycle cost process in the Air Force acquisition community. In their attempt to evaluate how well life cycle cost models captured various elements of the life cycle analysis process, the researchers discovered that the entire life cycle cost process was not clearly defined within the Air Force acquisition community. One of the primary results of this finding was the recommendation to classify life cycle costs into the research and development, investment, and operating and support categories, along with various subcategories (31:6).

The Rand researchers evaluated six of the most commonly used life cycle cost models in use at the time. Figure 2 describes each model evaluated. This figure briefly explains the classification of each model, its main purpose, and the relevant strengths and weaknesses of each model as highlighted in the Rand Report.

The Rand report was critical of all life cycle cost models they evaluated. In their conclusion they stated:

MODEL	CATEGORY	FUNCTIONAL DESCRIPTION	LIMITATIONS
* Budget Annual Cost Estimating(BACE)/ Cost Analysis Cost Estimating(CACE)	Accounting Models	Used to generate cost estimates for exercises, research, life cycle cost studies	* Sensitivity limited to flying hours, squadron size, manpower * AFR 173-10 cost factors used in model not consistent throughout USAF
* Logistics Support Cost(LSC)	Accounting Model	Builds operating and support cost estimates	* Does not consider some important life cycle cost categories * Assumes linear cost relationships that may not exist
* Logistics Composite (LCOM)	Simulation Model	Simulates *airbase logistics* support operations	* *Requires large number of* data inputs * *Limited ability to predict* logistics policy changes
* Multi-Item, Multi-Echelon, Multi-Indenture Inventory (MOD-METRIC)	Inventory Management Model	Used to determine optimal inventory levels	* Assumes theoretical probability distributions in USAF historical data that may not exist
* Development and Production Costs of Aircraft(DARPA)	Cost Estimating Model	Used to estimate aircraft development and procurement costs	* Does not estimate costs for avionics systems
* Programmed Review of Information for Costing and Evaluation(PRICE)	Cost Estimating Model	Estimates development and production costs of systems with both mechanical and electronic components	* Proprietary model; accuracy of regression model unknown

Figure 2. Models Evaluated in the Rand Report (31:18-39)

> The principal message that emerges from our research is that current LCC models contain many shortcomings that limit their usefulness for life cycle analysis of major modification proposals or other applications requiring estimates of absolute incremental cost (31:40-41).

Additionally, they concluded the primary reason that the models were flawed in many areas was because they either poorly addressed causal relationships and cost driving factors of many of the life cycle cost variables or failed to address them all together.

How did they suggest the logistics support analyst handle this dilemma? Their conclusion in light of the previous finding was rather straightforward. They recommended:

> When the evaluations (of the six models) indicate that a proposal's principal cost driving factors and cost elements are addressed poorly (or not at all) the models should be used cautiously, and any cost savings predicted should be strongly supported by additional analysis or empirical evidence (31:41).

One of the critical assumptions the Rand report seemed to infer was that most life cycle cost studies needed to make absolute incremental cost estimates (31:40). Often, as in the case of the PRAM Program office, this assumption does not hold. Unfortunately, while acknowledging that life cycle cost studies may be undertaken with only an interest in relevant or approximate cost estimates, the Rand researchers do not address the issue of the appropriate use of these models in making any rough LCC estimates.

During the course of this study, the researchers discovered that obtaining the appropriate input data for these life cycle cost models proved to be a very daunting task indeed, while optimistically stating, "with sufficient effort and time, it should be possible to overcome the main methodological problems and data deficiencies of life cycle cost analysis" (31:42). Eleven years later, however, the problem of serious data deficiencies is still a very significant problem in life cycle cost analysis. It is a problem that has very broad implications for the use of life cycle cost models as well as a host of other logistics models. Unfortunately, this problem seems to be one that is rather intractable.

Another issue that the Rand researchers did not concern themselves with was the issue of man/model interface. Although they criticized the models heavily for not capturing the proper cost driving factors or cost element relationships, they did not discuss the amount of training needed by analysts to properly interface with each model. The only hint of this problem comes when they discuss the bulky nature of the Logistics Composite (LCOM) model, and the large number of inputs it requires (31:25).

One issue that logistics modeling literature did not address before the 1980s was the issue of model portability. Additionally, the issue of using logistics models on various computer systems has received attention only in the most recent literature.

These issues, as well as a host of others concerning the use of logistics models on computer-based systems, surfaced as a direct result of the introduction of inexpensive and powerful microcomputers during the early and mid-1980s. Prior to this major technological advancement, the use of logistics models required interface with computer systems groups, management information services personnel, or other data processing departments (40:39). The development of logistics models, prior to the introduction of the microcomputers, was always a prolonged and expensive task, requiring the efforts of many programmers and extensive mainframe computer resources. As a result, computer-based logistics support analysis was often a complex task and many early attempts at using computers to perform this type of analysis were eventually abandoned (44).

These early failures soured many logistics support analysts on the use of models and computers for performing any logistics support analysis. Genet's and Demmy's advice to new logistics analysts concerning the use of computers and logistical models is thought to be an example of this earlier frustration. They warn the new analyst to be extremely cautious when using the computer to perform logistics support analysis. They state:

> Be forewarned that (computer) programs take five times as long to write as planned. Computer programs never work right the first, second, third or forth time. Computers always go down when you need them most (20:39).

Additionally, in warning against the use of computerized logistics models, these authors declare:

> Be informed that canned simulation models always require lots of input data that you will not be able to get no matter how hard you try (so you will end up guessing). Also be informed that canned models usually contain hidden undocumented critical assumptions that will leap out and grab you at the last moment, when it's too late to recover (20:39).

These warnings against what Genet and Demmy call the "twin diseases of computeritis and modelitis" are very important. The improper use of computers and canned models by novice analysts can lead to improper analysis and poor decisions. However, implied in these warnings was a sense of frustration experienced by many logisticians concerning the complexity of using these large models on the existing computer mainframe technologies of the 1970s.

The introduction of inexpensive microcomputers with very large and powerful memories overcame many technological barriers that previously existed in logistics model development efforts. Additionally, along with the introduction of this new microcomputer hardware, came a host of improvements in application software. The end result has been a development of an entire new generation of general and specific computer software that allows the logistics support analyst and program manager to more readily take advantage of the logistics support modeling environment.

The variety of microcomputer tools now available for use by the logistics support analyst covers a very broad spectrum from simple spreadsheets to more complex programs which use cost estimating linear regressions and probability distributions to represent historical data. These new tools have given the analyst ever increasing flexibility in performing supportability analysis of complex weapon systems. Additionally, these new software applications require little or no computer expertise to operate. As a result many logistics analysts, program managers, and even senior Air Force managers are beginning to use microcomputers to assist them in tactical and strategic decision making. As microcomputers become even more powerful and the software becomes even easier to use, there is little doubt that this trend will continue.

As a result of recent technological advances, a continuum of logistics support microcomputer models has developed within the last five years. As Figure 3 illustrates, the range and scope of models that exists along this continuum varies from tailored models designed by analysts using existing commercial software products to composite modeling efforts designed to more completely integrate functional logistics areas with different functional measures of merit.

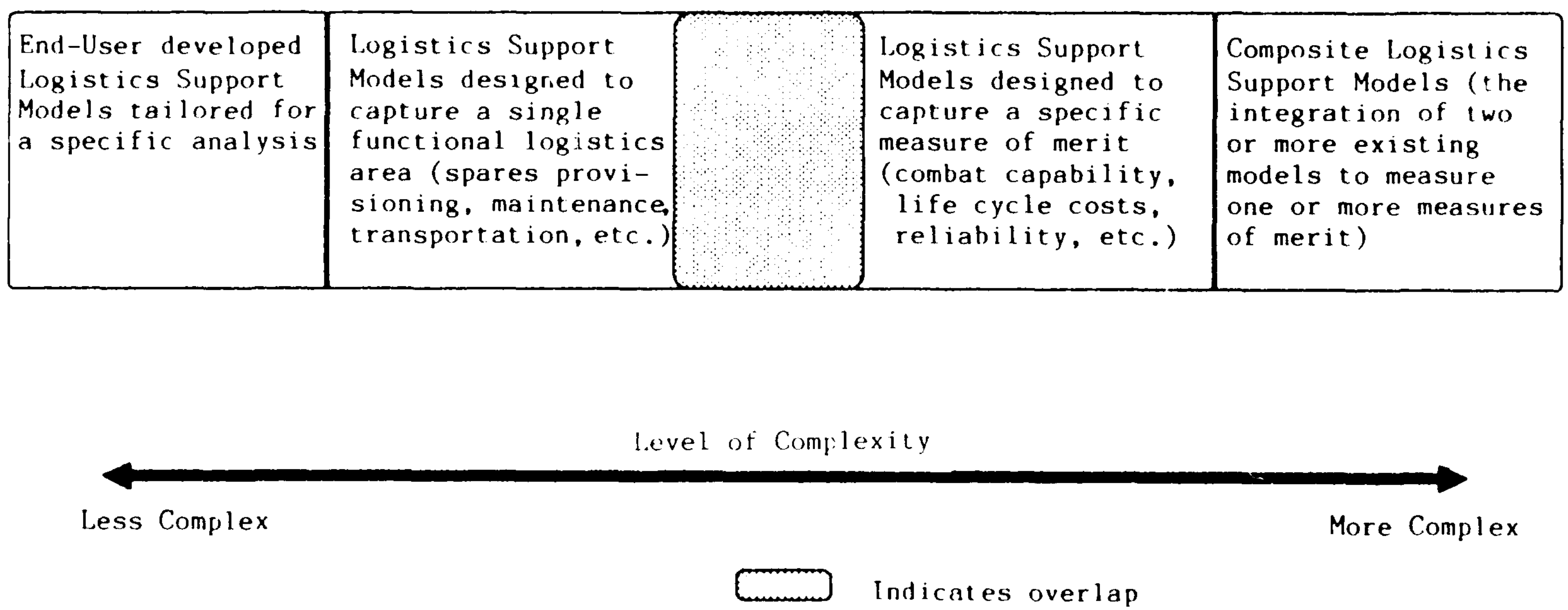

Figure 3. Continuum of Microcomputer Logistics Support Models

Green provides the reader with one example of a tailored model through his use of a standard commercial spreadsheet package to perform simple life cycle cost analysis (22:33). He took advantage of simple spreadsheet modeling methods and several financial functions built in to the spreadsheet. The result was a simple-to-use, customized life cycle cost model which allowed the user to quickly compare the life cycle costs of several alternatives and easily change any factor in the model in order to perform sensitivity analysis. Additionally, it was designed to capture the net present value of the various alternatives examined, allowing the decision maker to evaluate all projects in light of current dollars (22:34).

Green assumes that most analysts will be familiar enough with microcomputer applications so that learning how to use a spreadsheet will not be difficult. He concludes by stating "spreadsheet-based life-cycle analysis can yield a valid result with a reasonable amount of investment of time and energy" (22:36). This common microcomputer application can become a useful tool for the logistics support analyst in only a matter of days, allowing the analyst to perform not only accurate life-cycle cost analysis, but a host of other logistics support studies that use complex mathematical formulas.

Many other tailored logistics models have been developed by a variety of Air Force analysts. As microcomputer application software becomes more oriented to business and government managers as their primary customers (as opposed to computer science professionals), the traditional distinctions between the managers as end users of models and managers as model builders has often become blurred. End-user model development allows the logistics support analyst to bypass many developmental difficulties, in terms of time and effort, that exist by using more traditional Air Force methods of software development.

The Air Force is actively encouraging this user-developed software modeling effort in assisting decision makers efforts to solve a wide variety of logistics support problems. To further this effort, the recently established Information Systems Technology Application Program (ISTAP) was developed to "advocate the use of commercial software, programming aids, and end-user development to facilitate (Air Force) software production" (46:22). The ISTAP hopes to have over 50 percent of all new Air Force software user-developed by the end of FY 1989 (46:22).

Not only has the microcomputer revolution produced a wide range of user-developed models, it has been responsible for a host of more sophisticated models which seek to improve logistics support analysis in different functional logistics support areas. Examples of microcomputer models developed for specific functional logistics support areas are the recently developed Aircraft Availability Model

(AAM), a microcomputer version of a supply spares provisioning model and the Automated Air Load Planning System (AALPS), a microcomputer version of a transportation expert system designed to assist military transporters in calculating cargo load requirements for air transport (25:2-1).

In addition to the functional logistics models, one finds logistics models designed to capture a single measure of merit over a wide variety of functional logistics areas. While many of these models are more complex than those designed to measure a single functional logistics area, as Figure 3 illustrates, there are no distinct boundaries separating these two categories. Among some of the most widely used models in this measure of merit category are a number of models which are designed to capture weapon system and subsystem life cycle costs.

In the life cycle cost arena, two relatively new microcomputer-based life cycle cost models which are representative of this type of model are the Statistically Improved Life Cycle Cost (SILCC) model and the Cost Analysis and Strategy and Assessment (CASA) model. Although both are microcomputer based, they vary widely in scope.

The SILCC was designed primarily to provide Air Force logistics support analysts and program managers with the ability to perform life cycle cost trade off analysis down to the subsystem and component level (46:2). It was designed to calculate a wide range of life cycle costs, primarily focusing on operational and support costs, but evaluating all life cycle costs. It requires only 36 data inputs for each alternative being evaluated, and provides the user with 19 outputs for each alternative. These output categories are divided into four categories; numbers of spares required, number of maintenance hours required, expenditures, and total life cycle costs (37:26,30).

CASA, on the other hand, is a more complex life cycle cost model designed to be used by a wide range of program managers and logistical analysts throughout the Department of Defense (25:30). The CASA model:

> provides automated support for LCC estimates, trade-off analysis, repair level analyses, production rate and quantity analysis, warranty analyses, spares identification, resource projections(maintenance planning), risk and uncertainty analysis, cost driver sensitivity analysis, reliability growth analysis, evaluation of engineering change proposals, operational availability analysis, spares optimization, and design to life cycle cost studies (25:30).

This model has six major modules and was designed to run on an IBM-compatible microcomputer. The development and use of this complex LCC cost model on a standard microcomputer would not have been possible less than a decade ago.

The most recent advancement of logistics support model technology is composite modeling. Composite modeling seeks to combine two or more logistics support models into a single, integrated model in an effort to capture causal relationships between several different measures of merit. Within the military, composite modeling also attempts to bridge the current gap between peacetime efficiency models and those models that attempt to assess the wartime logistics support capabilities.

Two models which are representative of recent composite modeling efforts are the System Cost Operational Performance for Modification (SCOPE-MOD) model and the Logistics Assessment Methodology Program/Logistics Assessment Work Station (LAMP/LAWS). Both of these models are integrated composites of other complete models. Both models were also designed to integrate all five of the Air Force's R&M 2000 goals into a single model to allow an Air Force program manager to perform trade off analysis between warfighting capability, survivability, mobility, manpower, and life cycle costs (39:1-1;45:45).

SCOPE-MOD was designed to provide logistics support analysts with a comparative model that evaluates how "proposed R&M modifications will enhance R&M 2000 goals" (39:1-2). It is the combination of two distinct models, DYNAMOD and MICROSTRAT.

DYNAMOD, a "logistical pipeline model", was designed using the same methodology developed for the popular DYNA-METRIC spares provisioning model produced by the Rand Corporation (39:B-2). Designed to determine warfighting improvements of proposed R&M alternatives at the squadron level, it uses R&M data, spares data, and typical wartime flying scenarios to predict 30-day aircraft availability and sortie rates at the squadron level for a variety of weapon systems (39:2-4).

The second model integrated into SCOPE-MOD, MICROSTRAT, computes weapon system life cycle costs. The model computes both investment and annual operating costs for a two different sets of components; the baseline set and the modified set. The resulting output compares both the annual and cumulative life cycle costs of the weapon system baseline component set to the same weapon system with the modified component set (39:D-2).

Like SCOPE-MOD, LAMP/LAWS is a composite modeling effort that integrates several models in an effort to provide a complete R&M 2000 goals assessment. Unlike SCOPE-MOD, however, LAMP/LAWS integrates six previously accepted DOD logistics support models in its effort to capture all of the R&M measures of merit (24). Figure 4 lists and briefly describes the six models used for calculating LAMP/LAWS outputs.

Since the introduction of practical microcomputer technology, the pace of both hardware and software developments has been astounding. Both hardware and software technology are often obsolete within a year after they are introduced. Microcomputer technology is in a continual state of flux, with new hardware and software products being developed almost weekly.

MODEL	FUNCTIONAL DESCRIPTION
* DYNA-METRIC (D-M)	Used to compute war-time surge capability of spares pipeline
* Support Systems Effectiveness and Cost (SEAC)	Computes peace-time steady state spares pipeline
* Interactive Manpower Personnel assessment and Correlation Technology (IMPACT)	Given workload variables, generates personnel requirements
* Training and Manpower (TRAMP)	Used to compute training costs
* Logistics Support Cost Model (LSCM)	Standard ALFC cost model that measures a wide range of life cycle costs
* Aircraft Availability Model (AAM)	Spares provisioning model based on aircraft availability

Figure 4. Accepted DOD Models Integrated into the LAMP/LAWS Composite Model(27)

This state of rapidly changing microcomputer technology has been probably one of the key factors in the substantial growth of composite logistics models. While still a very complex process, the time needed to integrate complete logistics models into a single composite package has decreased exponentially. During a recent logistics support conference, one model developer recently pointed out that his company's first effort at composite modeling took about ten months. Less than two years later, the time this same company needed to develop a composite modeling package was less than three months (26).

While this rapid growth in modeling capability is touted by the model developers as a great boon for analysts and decision makers alike, it also has some very distinct disadvantages. Probably one of the biggest drawbacks is the large delay created between model development and independent model validation.

As with any analytical tool designed to aid decision making, microcomputer logistics support models will not gain widespread acceptance from those responsible for performing supportability analysis unless they can be used with some known degree of confidence. Ideally, model developers confront this confidence issue through verification and validation (38:33). Verification is the process of ensuring the software operates properly and its implementation of the model is conceptually correct. While this process may be complex and time consuming, it is the rather straightforward task of ensuring that the computer programming faithfully reproduces the algorithms and procedures of the model (38:33). This task pales, by comparison, to the more difficult job of model validation.

Model validation is the process of making sure that the "working" computer model captures the real system adequately enough for use in problem solving (5:5-5). While there are many different ways to validate model, Hallam, et al., define five general steps of proper model validation. They include:

1. Establishing goals and assumptions of (the) model in writing.

2. Test (the) rationality of the assumptions.

3. Test (the) statistical validity of crucial assumptions.

4. Compare model output to historical output.

5. Test validity of predictions (23:83).

Hallam goes on to make an extremely important point about models. While specifically addressing simulation models, the comments made in this article apply to micro-computer-based models as well. In making an analogy between simulation models and toys, Hallam asserts:

> A model without validity may ... bear some resemblance to its real counterpart, but it too is useless except perhaps to delight or entertain. Without proper validation, the computer model is merely a toy" (23:83).

If the model is merely useless, there would be little cause for alarm. However, when an invalid model is assumed to be valid by the decision maker, they can become dangerous. Again, Hallam contends:

> Computerized...models are particularly dangerous because, for many persons, output from the computer is automatically considered accurate. The danger arises when the decision-maker assumes the toy is valid and bases decisions accordingly (23:83).

The bottom line on model validation is gaining the confidence of the user community that the model can reasonably accomplish its intended tasks over a wide range of analysis.

Because of the difficulty inherent in validation, only a few microcomputer models have reached the broadest level of acceptance within the use community. While many microcomputer models have their own individual champions, many analysts are skeptical of the validity of many of these newly developed microcomputer models.

Contributing to this skepticism is a general lack of formal studies that thoroughly document the overall strengths and weaknesses of these models. Additionally, fewer still actually discuss the mathematical or statistical validity of microcomputer models. Most of the documents this thesis author was able to uncover concerning computer validity were manuals or guides published by the contractors responsible for developing the models. These reports concentrated more on discussing the virtues of the model and their specific mathematical and/or linear regression formu..s than specific validity issues. While these contractor manuals may indeed help to validate the model, the user community will more readily accept a model that has been independently validated. Unfortunately, independent formal case studies on specific microcomputer models are difficult to uncover.

Tovrea accomplished one such study on LAMP/LAWS. The purpose of his research was to demonstrate the validity of LAMP/LAWS as an assessment tool for the potential modification of a specific subsystem on the F-15 aircraft (45:2-3). After gathering a considerable amount of supportability data on two different versions of the AN/ALQ-135 Internal Countermeasures Set, Tovrea first used LAWS to perform direct performance comparisons of the original configuration of the AN/ALQ-135 with the proposed modification, across the five R&M measures of merit. He then performed extensive amounts of sensitivity analysis to ascertain what changes LAMP/LAWS predicted. For example, if he made reductions to the amount of aircraft available because to wartime attrition, he wanted to see how LAMP/LAWS would predict a reduction of combat capability as well as a reduction in the number of spares required (45:131).

Tovrea was able to use LAMP/LAWS to make a wide variety of supportability assessments about the original configuration of the AN/ALQ-135 versus the proposed modification. Based on the output from the LAMP/LAWS model, he concluded that the proposed modification offered large supportability improvements over the existing configuration in every R&M 2000 goal except life cycle cost (45:154). Additionally, he was able to conclude, based on LAMP/LAWS outputs, how changes in maintenance policy, levels of support equipment, repair cycle time, and mean time between failure of the two different alternatives would affect all five R&M 2000 goals.

While Tovrea was able to use LAMP/LAWS to perform a very comprehensive supportability assessment of two alternative subsystems of the F-15 aircraft, he also concluded that, for its stated purpose of supportability assessment, the model was incomplete as he had used it. While he noted the model which he used was a prototype, there were still software "glitches" that constrained the analysis process (45:149). Of particular importance was his note that "some of the input variables were inexplicably 'unsensitizable' due to unexpected dead ends in the 'What-if' options" (45:149). This prevented him from performing a number of sensitivity analyses, which may or may not have affected the final overall analysis. He also noted that some variables in LAMP/LAWS were either defined vaguely or incorrectly (45:149).

Another issue pointed out by Tovrea was the tremendous effort needed to accumulate enough data to properly run LAMP/LAWS. While he noted that a positive benefit of the data collection effort was a better understanding of the "assumptions and real-world factors underlying the data", one might just as well argue that if the true purpose was to make LAMP/LAWs a truly effective tool in aiding the decision making process, the model developers should have spent more time and effort making the data collection process less painful (45:57). The model developer did indeed take note of this data collection issue, and developed a data pre-processor for LAMP/LAWS in order to greatly simplify the data collection effort.

Minnick accomplished another model validation study which performs model validation by comparing the output of two similar microcomputer-based life cycle cost models using the same input data (33:331). He compared the results of the Cost Analysis and Strategy Assessment (CASA) model with a version of the Logistics Support Cost Model (LSC) that has been adapted to capture all relevant life cycle costs (33:331).

Minnick constructed hypothetical data sets for a generic infrared detecting system that was supposed to have a useful system life of 20 years. When he ran both models using the same input data set at the beginning of the study, Minnick noted that the difference in bottom line LCC costs between CASA and LSC was over $67 million dollars (a 23.1 percent difference in total LCC) (33:334). Even after making changes to the input data in an effort to achieve data parity between the two models, the end results were still over $37.5 million dollars apart (a 13.4 percent difference in total LCC) (33:334).

Not only did the models differ with respect to bottom line life cycle costs, they offered differing levels of sensitivity analysis. For example, in CASA, if the mean time between failure (MTBF) was decreased by 10 percent, the effect on LCC was a 7.8 percent increase. By contrast, the same 10 decrease in MTBF in LSC caused more than a 10 percent increase in reported LCC (33:334).

Minnick noted that the key reason for the variations between these two models was due to the differing assumptions made about aircraft flying hours. CASA used a "phase-in" approach to aircraft hours at the system level; it assumed that not all of the aircraft would be available for operational use at the beginning of the life cycle. LSC, on the other hand, assumed that all aircraft were available from the beginning of the weapon system life cycle. It did not assume any build up of activity over a period of time. The difference between these two assumptions was over 142,000 operating hours over a twenty year period; CASA having amassed 3,600,000 operating hours versus 3,457,500 operating hours for LSC (a 4 percent difference) (33:335).

Other differing assumptions caused similar disparities for a host of other operational and support (O&S) categories. These differing assumptions caused over a 24 percent variance between equipment maintenance costs, a 12 percent variance between condemnation spares costs, a 9 percent variance between pipeline spare costs, as well as similar variances in a wide range of other O&S costs (33:335).

Although Minnick points out O&S costs differences in various categories, except for citing the reason for the differences in operating hours, he does not clearly indicate why he thinks the cost numbers were so different. Additionally, after spending the bulk of his article addressing the output differences between the two models, he ends by arguing that "both models produce reasonable results" (33:336). However, he does not explain what he means by this statement, except to say "both models have applications in training, conceptual work, and full-scale development phases for equipment that functions in an operating environment". One can only assume that Minnick is suggesting that for preliminary LCC cost estimates both models are adequate. Additionally, Minnick clouds the model validation issue by stating that CASA was more robust than LSC, without explaining his rationale for this statement.

The Supportability Investment Decision Analysis Center (SIDAC): Making Sense of Microcomputer Logistics Support Models

While the issue of validity is fundamental to model use, with the recent explosion in the amount of microcomputer-based logistics support models available, even a more basic concern for many logistics analysts and decision makers has been simply how to obtain enough information on existing models to make rational decisions concerning their applicability and use. Many analysts within the Air Force supportability community simply do not know where to start looking for information concerning quality supportability analysis methodology, data or models needed to perform more complete analyses.

Supportability managers and analysts throughout the Air Force have been seriously concerned about these deficiencies in supportability assessment. Because of these concerns, the Air Staff, along with many separate agencies within AFLC and AFSC, have recently undertaken many separate efforts to improve the quality of supportability analysis and decision making (8:1).

During the 1988 AFLC Logistics Operations Center's (LOC) R&M Modeling Conference, many of these efforts were examined and evaluated. One "overwhelming recommendation" emerging from this conference was an initiative to study the feasibility of establishing a joint AFLC/AFSC supportability analysis center (9:2). Through the development of the Supportability Investment Decision Analysis Center (SIDAC), both AFLC and AFSC hope to "improve and apply analysis methods, models, and techniques, and enabling services for every aspect of weapon system supportability" (9:1).

Although this center is only in the Concept Exploration stage, if the concept proves feasible, the SIDAC eventually will provide a wide variety of services to supportability analysts.

Proposing to function along the lines of traditional DOD Information Analysis Centers, SIDAC objectives include:

1. facilitating the exchange of information between AFLC and AFSC communities,

2. promoting awareness and use of effective analysis methods and techniques,

3. eliminating technical barriers which limit the effectiveness of modeling and qualitative analysis techniques,

4. identifying and providing quality data and information (8:1).

The proposed SIDAC would facilitate these objectives by providing the Air Force supportability community with a variety of 'value-added' technical services that would assist a wide range of Air Force analysts and managers in their supportability investment decision making efforts. These services would include providing assistance with analysis methods; identifying, cataloging, evaluating, and providing technical support for a wide variety of logistics support models; providing SIDAC customers with methods to improve logistics support data collection efforts; providing the supportability community with a host of 'corporate' communication services; establishing a technical repository for supportability "models, methods, and data access techniques"; and finally, undertake special studies and tasks requested by members of the user community (9:2-3).

The SIDAC concept is timely; establishing a central clearing house for the complex maze of existing logistics support analysis methodologies and models would significantly reduce the amount of time spent by analysts in searching for appropriate methods and models needed for conducting logistics supportability analyses. Additionally, as many logistics support analysts and managers do not have an extensive background in operations research or other sophisticated analysis techniques, the successful implementation of the SIDAC would greatly enhance the credibility of the entire supportability decision making process. A SIDAC program manager echoed this point recently by saying, "One of the long term goals of the SIDAC should be to provide the same credibility to logistics methodologies and models that currently exists in the operational community" (41).

III. Methodology

Introduction

This chapter provides the strategies and techniques used to answer the research question proposed in Chapter 1. This includes:

1. the phases of the research process;

2. the method of PRAM proposal selection;

3. the means of determining the level of management analysis and amount of data required for adequate analysis of each proposal;

4. the method of matching analysis requirements with appropriate logistics supp rt models, and finally;

5. how logistics support models were used for data analysis.

Phases of the Research Process

This research began with an literature review which investigated technology insertion, the PRAM Program office and its process, reviewed literature discussing research conducted using microcomputer-based logistics support models, and detailed recent AFLC/AFSC efforts to assist the logistics support community by exploring the feasibility of SIDAC. Based upon a review of current literature, a pilot study was developed to examine the application of a tailored methodology for using microcomputer-based logistics support models. As such a large portion of the research methodology was exploratory in nature. The population of concern in this study was narrowly defined to recently active PRAM Program Office projects. Three projects were chosen for analysis during the project selection phase of the study. The projects were chosen on the basis of the management decision required, and how well the project represented the range of typical PRAM projects. More will be said about this topic later.

After project selection, exploratory analysis was conducted to determine the nature of the management decision required for each project. During this phase a preliminary assessment was also made to determine the amount of data available for an analysis of each project.

The next phase of the research involved an initial survey of logistics support models to determine what models had the capabilities to accomplish the analyses required by each project.

After this initial model survey was conducted, additional data was gathered on each project. This step was necessary because the existing data on all projects was insufficient to drive even the most basic model considered for use. The models under consideration for use were all examined for common data elements needed, after which a data sheet was formulated to gather most of the additional data required to drive the models (See Appendix A).

The final model selection process occurred only after this extensive data gathering effort was completed for each project. It was during this phase that each project was matched with a microcomputer-based computer logistics support model for quantitative analysis consistent with the level of management decision required.

The final phase of the research included the quantitative analysis of each selected PRAM project proposal and the report of the findings. This included a report of the quantitative improvements (or decreases) in the measures of merits reported, how the quantitative analysis of each proposal affected overall analysis, any limitations of the models used, and finally conclusions and recommendations for follow on research.

PRAM Proposal Selection

The projects chosen for research were selected by the PRAM Program Manager/Division Chief, Lt Col Charles Ferguson, and the deputy PRAM Program Manager/Division Chief, Mr. John Tirpack. Lt Col Ferguson and Mr. Tirpack selected these projects based on qualitative criteria. The criteria used to select each proposal were:

1. How well the type of project represented the range of typical PRAM projects.

2. The degree of qualitative uncertainty generated by each proposal.

3. The overall cost of each project.

The decision criteria is highly qualitative and may be subject to the bias of the PRAM Program Director and Deputy Director. However, both men had the highest level of broad-based PRAM project management, and were the best qualified personnel within the PRAM Program Office to perform project selection.

Determining the Level of Analysis Required

The level of analysis required was a function of two elements. First the supportability assessment decision desired for each project was determined through an analysis of each PRAM project plan and interviews with each PRAM project manager. Additionally, senior PRAM managers were interviewed to further determine the exact nature of the supportability assessment information desired for final project approval.

After the nature of the logistics support decision required by management was ascertained, each project was reviewed to determine the amount and exact nature of data available to perform a quantitative analysis on each project. Information regarding data availability was gathered through a review of each project proposal, exploratory interviews with PRAM project managers, and exploratory interviews with other AFLC/AFSC logistics personnel.

Initial Microcomputer-based Logistics Model Survey

After the exact nature of the supportability decision and amount of quantitative data available were determined for each proposal, a matrix was used to place each project into one of three categories of analysis. The three categories represented a continuum of quantitative analysis, progressing from preliminary analysis to very detailed analysis, with proposals that needed a moderate amount of analysis being placed in the second category.

Once each project was classified, an in-depth search was made to select several microcomputer-based logistics support models that might be appropriate for use with the various proposals. These models were identified by a variety of means. The model catalog under development by the SIDAC concept exploration team was the main source of candidate model identification. After potential models were identified, the various offices of primary responsibility were contacted in order to obtain the appropriate software and documentation. Finally, once the models were obtained, their analytical capabilities were ascertained and their data inputs were examined.

Additional Data Collection Efforts

After an examination of the data inputs required for all candidate logistics support models, it became quite evident that a considerable amount of additional data had to be gathered to drive any of the models being considered. After examining the data input requirements of all candidate models, a standard data collection form was devised in order to facilitate these additional data collection efforts. A draft copy of the SIDAC data catalog was then consulted to locate Air Force data systems that contained these required data elements. Various data experts at the PRAM office and the Air Force Institute of Technology (AFIT) were also consulted during the additional data collection effort.

Final Model Selection

Only after these data element forms were completed, and several standard cost elements were gathered, did final model selection occur. Criteria for final model selection were as follows:

1. depth/breath of analysis required;
2. compatibility of data with model.
3. validity of model;
4. sensitivity analysis capability, and,
5. overall ease of use.

Each project was evaluated using only one model. The final model selection decision was made by the researcher after consultation with modeling experts from AFLC, AFSC and the SIDAC concept exploration team at AFLC/LOC and Dynamics Research Corporation.

PRAM Project Proposal Analysis Using Selected Models

Once all the initial data had been analyzed and a model selected for each proposal, the models were used for performing the quantitative analysis of each proposal. The results of the quantitative analysis are reported in the findings section. These findings include results of initial computer analysis, comments on the ease of performing sensitivity analyses, and the limitations on the use of these computerized quantitative techniques.

IV. Analysis and Findings

Project Selection

Senior PRAM management selected the following three projects for use in this study:

1. The F-15C/D Main Landing Gear Wheel Improvement project.

2. The C-141A/B Variable Speed Constant Frequency Electrical Generating System project.

3. The improved power supply project for the AN/ALR-46/69 Signal Processor.

All projects had been evaluated by the PRAM staff in an initial PRAM Project Plan. Included in each of these plans was a specific recommendation by various members of the PRAM staff for approval or disapproval of each project. For reasons explained below, PRAM management was interested in how quantitative analysis using microcomputer logistics support models would collaborate or refute the staff recommendations.

Description of Selected Projects

F-15C/D Main Landing Gear Wheel Improvement.

Although the current aluminum alloy wheel (referred to hereafter as the 2014 wheel) on the F-15C/D main landing gear performs adequately and the wheel lasts about 10 years, this project was the result of an unsolicited proposal submitted to the PRAM office in December 1988, by the Bendix

Brake division of Allied Signal Corporation. This proposal suggested that by purchasing a superior aluminum alloy wheel made by Allied Signal in future procurement, the Air Force would realize substantial operational and support cost savings through reductions in depot overhauls of the wheels (13:1).

What allegedly makes the Allied Signal wheel superior to the existing wheel is the use of a rapid solidification technology (RST) process along with powder metal technology. According to the proposal submitted by Allied Signal, the RST wheel will have nine times the corrosion resistance, three times the high temperature strength, and last 50 percent longer than the existing wheel (13:1).

PRAM management selected the improved F-15C/D aircraft wheel project for inclusion in the study because they felt it was representative of a typical PRAM project. Additionally, PRAM management expressed an interest in more accurately quantifying any economic cost savings generated by this project. Another consideration was the large expenditure of PRAM project development costs for this project (over $800,000 dollars) (17).

<u>C-141A/B Variable Speed Constant Frequency (VSCF) System</u>. This project resulted from an initiative undertaken by Military Airlift Command's Office of Logistics Reliability and Maintainability (MAC/LGR) in 1987. They were interested in evaluating the feasibility of replacing the man

power intensive constant speed drive electrical generating system on the C141A/B with a variable speed, constant frequency system (12:1).

Although this particular Candidate Project had been recently disapproved for further continuation as a active PRAM project, PRAM management was interested in determining if and how quantitative analysis, using microcomputer logistics modeling, would support the findings of the PRAM staff. Another factor which drove the selection of this project for the study was the high degree of controversy surrounding the use of the constant speed drive electrical generating system versus the variable speed constant frequency system. An additional reason for inclusion of this project in the study was the high PRAM development costs as well as Air Force C-141 fleet implementation costs. The cost of the PRAM development project was to be $4 million dollars, with the implementation costs to the Air Force of at least $107 million dollars.

<u>AN/ALR-46/69 Signal Processor Power Supply Improvement</u>. The AN/ALR-46/69 Radar Warning Receiver (RWR) is used by many weapon systems throughout the Air Force as an intricate part of their overall electromagnetic countermeasures (ECM) system. Within the RWR, the signal processor unit plays a critical role in detecting hostile radar signals. It is crucial, therefore, for the signal processor to work correctly when required.

However, many problems exist with the current Signal Processor Power Supply. The existing power supply design has inefficiencies which contribute to overheating problems. Additionally, demands on the existing power supply can escalate to a point that the electrical output of the power supply becomes unsatisfactory. As a result, the Systems Engineering Branch at Warner-Robbins Air Logistics Center proposed to improve the AN/ALR-46/69 Signal Processor Power Supply through redesign (10:2,3).

Senior PRAM management saw this as an ideal project to include in this study. Since the project was a proposal for a form, fit, and function improvement of a component across several different weapon systems, each with its unique characteristics, they felt that any analysis of economic costs and benefits would prove difficult. Senior PRAM management was, therefore, very interested in how supportability analysis using a microcomputer-based logistics support model would meet this challenge. Additionally, during the course of this study, the project development cost doubled. PRAM management expressed a desire to quantitatively examine how these higher development costs would affect the project [illegible].

Determination of Analysis Level

Before a search was undertaken for supportability assessment [illegible], it was necessary to [illegible] the level [illegible] analysis that each project required. This was accomplished in three steps. First both senior PRAM management and each project manager were interviewed in an effort to determine the exact nature of the supportability decision desired for each project. Next, each PRAM Project Plan was carefully examined, with all appropriate quantitative data extracted for later use. Finally, the PRAM manager of each project was interviewed to fill in as many 'gaps' in the data as possible.

F-15C/D Improved Wheel. The decision orientation for the F-15C/D improved wheel was directed toward life cycle costs (LCC). This was based on the fact that the initial unit cost of the proposed wheel was over $1000 dollars higher than the unit cost of the existing wheel. Since the existing wheel provided adequate reliability, in order for this project to be considered a success, any analysis needed to demonstrate reductions in operating and support costs over the useful life of the F-15C/D aircraft (47).

The PRAM Project Plan revealed only a very brief economic analysis. As outlined in Table 1, the F-15C/D Improved Wheel Project Plan disclosed all the major elements of PRAM development costs, and only ten data elements for each alternative's operational and support costs. Further analysis showed that almost all of the data listed in the project plan came exclusively from the contractor proposal.

Table 1

Original Data Available for
F-15C/D Improved Wheel

A. PRAM Program Cost

Activity	Cost
Wheel Material	$450,700
Forging Processing	$131,600
Wheel Machining	$50,600
Material Characterization	$68,500
Brake Material	$57,500
Data Analysis	$87,500
Total PRAM Project Cost	$846,500

B. Comparison of 20 Year ULS* - 2014 vs RST Alloy

	2014	RST	Savings
Wheel Cost per Unit	$6000	$7800	($1800)
Wheel Life, Years	12	18	
Wheel Cost per Year	$ 500	$ 433	
Overhaul Cost per Wheel	$1500	$1000	
Overhaul Cycle in Years	2	4	
Overhaul Cost per Year	$ 750	$ 250	
Total Wheel Cost per Year	$1250	$ 683	$ 567
Annualized Cost of Fleet	$1175000	$642333	$532667
20 Year Cost of Fleet	$23500000	$12846667	$10653333

Savings Per Year	$532667
Return on Investment over 20 years	12.6

* Useful Life Savings

C-141A/B Variable Speed Constant Frequency (VSCF) System. The decision orientation for the VSCF project had two dimensions. The major variables to be evaluated in this project were reliability and life cycle costs. Specifically, PRAM management wished to determine if the proposed improvements in reliability and reduction in operating and support costs of the VSCF system would outweigh the large project development and life cycle costs.

The C-141A/B VSCF System Project Plan indicated that a large amount of data had previously been collected for this study. Data outlined in this plan came from several different sources; from contractors, various Air Logistics Centers, Military Airlift Command, and numerous AFLC and ASD agencies located on Wright Patterson Air Force Base (12:8). Additionally, an extensive amount of data was obtained from the Reliability and Maintainability Data Analysis System (RAMDAS) as well as supply system and depot overhaul reports in a subsequent analysis (36:1). Table 2 lists all data available for the C-141A/B VSCF project.

AN/ALR-46/69 Signal Processor Power Supply

The decision orientation for the power supply analysis consisted of three dimensions. The major variable[illegible]ving this project were reliability, maintainability, and life cycle costs. Specifically, PRAM management sought to determine exactly how proposed improvements in reliability and

Table 2

Original Data Available for C-141 VSCF System

A. PRAM Project Cost	
Total Project Cost	$4,000,000
B. Implementation Cost	
VSCF Contractor Non-recurring	$3,000,000
VSCF Contractor Recurring	$107,205,500
Airframe Non-recurring	$1,600,000
Airframe Recurring	$16,260,000
Total Implementation Cost	$132,065,500

C. Comparison of CSD versus VSCF costs

	CSD	VSCF	Savings
Annual Depot Repair	$2,755,424	$ 300,000	
25 Year Depot Repair	$68,885,600	$7,500,000	$61,385,600
Annual Base Repair	$ 391,680	$ 64,000	
25 Year Base Repair	$ 9,792,000	$1,600,000	$ 8,192,000
Total Useful Life Savings			$69,577,600
Return on Investment			0.51

D. Other Relevant Information

	Amount
Number of C-141A/B Aircraft	271
Number of CSDs Installed	1084
Number of Spare CSDs	923
CSD Unit Cost	$60,133.76
VSCF Unit Cost (Estimated)	$74,500.00
CSD Unit Repair Cost	$3,702.32
VSCF Unit Repair Cost (Estimated)	$3,000.00
CSD Mean Time Between Failure	1,595 hrs
VSCF Mean Time Between Failure (Est)	4,000 hrs
Annual CSD Depot Repairs	612
Annual Generator Repairs	316
Generator Unit Repair Cost	$1,550.00
Annual VSCF Depot Repairs (Est)	100

Table 3

Original Data Available on
AN/ALR-46/69 Signal Processor Power Supply

A. PRAM Project Cost

	Cost
Redesign Power Supply	$60,000
Fabricating and Demonstrating	$120,000
Operational Testing and Evaluation (OT&E)	$ 40,000
OT&E Level Three Drawing	$ 80,000
Total PRAM Project Cost	$300,000

B. Implementation Cost

None

C. Cost Comparison and Other Relevant Data

	Current	Proposed	Savings
Mean Time Between Failure (MTBF)	1950 hrs	10,000 hrs	
Power Supply Unit Cost	$4,160	$3,000	
Required Spares*	446	87	$1,493,440
Yearly Depot Repair Cost	$578	$70	
Yearly Depot Repairs	55.2	10.8(est)	
10 year Repair Cost	$ 324,024	$7,560	$ 316,464
Depot Repair Manhours per Unit	11 hrs	1.3 hrs	
Estimated 10 Year Manhour Repair Costs**	$ 281,255	$6,503	$ 274,751

Total Useful Life Savings	$2,084,655
Return on Investment	6.95

* Estimate of Total Spares Required over 10 year period
** Calculated by multiplying number of repairs required over ten year period by depot manhours required per repair and cost per depot manhour (DMH). DMH cost used was $46.32

maintainability of the redesigned Signal Processor Power Supply would reduce its operations and support costs.

A moderate amount of data existed for an economic analysis of the power supply. Table 3 lists the original data available from the PRAM Project Plan.

Categories of Analysis

Based on the decision orientation(s) of each project and the amount of data available for analysis, each project was classified into a distinct analysis category. These analysis categories represented a continuum of complexity, ranging from relatively uncomplicated analysis to studies which necessitated a high degree of analysis to accurately capture all essential elements required to make an informed decision. The projects were placed into these distinct categories of analysis in order to facilitate the search for the appropriate logistical support model. Table 4 reflects the category of analysis required for each project.

Table 4

Categories of Analysis for PRAM projects

	Analysis Category		
PRAM Project	Relatively Simple	Moderately Complex	More Complex
F-15C/D Improved Aircraft Wheel	X		
C-141A/B VSCF System		X	
AN/ALR-46/69 Signal Processor Power Supply			X

Rational. The F-15C/D Improved Aircraft Wheel project was placed into the relatively simple category because of the one dimensional nature of the decision orientation, as well as the limited amount of data available to perform the analysis. The decision orientation of the project was aimed solely at life cycle costs and only about 30 data elements were initially available for analysis.

The C-141 VSCF System analysis was placed into the moderately complex category because of the two dimensional nature of the decision orientation. PRAM management was interested in determining exactly how reliability improvements affected life cycle costs. Additionally, a fairly large amount of data was available for conducting the analysis.

It was hard to determine exactly where the AN/ALR-46/69 Signal Processor Power Supply project fit on the continuum of required analysis. While the three dimensions of reliability, maintainability, and life cycle costs tended to shift the required analysis all the way to the right, the incomplete nature of the initial data listed in the PRAM Project Plan made any complex analysis of this project difficult.

Initial Model Survey

After identifying the decision orientation(s) and the amount of data available for each project, an informal survey of supportability models was made in an effort to determine which models could possibly be used for project analysis. The initial starting point for the survey was the SIDAC model catalog. Additionally, informal discussions were conducted with members of the AFIT faculty and various AFLC and AFSC agencies.

The candidate models were initially selected based on their ability to run on a microcomputer, and their ability to measure one or more of the decision variables for any selected project. Based on these initial criteria, several microcomputer supportability models were identified as candidates for use in performing analyses. Candidate models included:

1. Statistically Improved Life Cycle Cost (SILCC). This model includes the capability to perform component life cycle cost analysis based on only a limited amount of data (37:ii).

2. The Logistics Analysis Methodology Program using the Logistics Analysis Work Station (LAMP/LAWS). This model includes the capability to measure a project's performance in terms of combat capability, survivability, manpower, mobility, and life cycle costs. This model can be used to measure how reliability or maintainability improvements affected not only life cycle costs, but other R&M measures of merit as well (28:2-1).

3. Logistics Support Costs (LSC). This model includes the capability to estimate costs of new weapon system pro-

curement and weapon system modifications. It also has the capability to determine the impact of design changes on a wide variety of life cycle costs (11:1).

4. Cost Analysis and Strategy Assessment (CASA). CASA is a group of Logistics and Life Cycle Costs models integrated through the use of option menus. CASA includes the capability to perform several supportability analysis tasks relevant to the three projects in this study, including:

* LCC Estimates
* Trade-off Analysis
* Risk and Uncertainty Analysis
* Cost Driver Sensitivity Analysis
* Reliability Growth Analysis
* Spares Optimization (7:1-1).

5. System Cost Operational Performance Evaluation for Modification (SCOPE-MOD). SCOPE-MOD incorporated the capability to assess how proposed changes in weapon system reliability and maintainability would affect the entire spectrum of R&M 2000 goals for that particular weapon system. It performs this analysis by comparing a 'complete' baseline data set for a particular weapon system with a data set including the proposed modification parameters. The output of the SCOPE-MOD models is designed to highlight the differences of the proposed modification and the current system in terms of both life cycle costs and various operational parameters, such as number of sorties generated.

number of targets destroyed, and aircraft availability (39:2-5).

6. Life Cycle Cost Analysis Program, version H for personal computers (LCCHPC). The LCCHPC model evaluated for this study was a microcomputer adaptation of the LCC-2 Life Cycle Cost Analysis Program. *LCCHPC included the capability* to "evaluate the costs of acquiring an avionics system and supporting it over its operational life" (19:1-1). The model also incorporates the ability perform comparative analysis of different support concepts, explore sensitivity of life cycle costs to several different critical parameters (such as turnaround times, mean time between failure (MTBF), demand rates, etc.), determine required spares levels, and identify important cost driving parameters (19:1-1).

Additional Data Collection Efforts

From the initial survey of microcomputer logistics models available for performing FRAM project supportability analysis, it became evident that the data used for accomplishing previous studies was not going to provide enough detail to allow the use of even the most basic logistics support model. In order to use any of the candidate models, it was clear that much more additional data would have to be collected.

In order to facilitate this additional data collection effort, a form was designed to facilitate data collection.

Several models were examined for common input elements and a standard data collection format was designed to assist in gathering additional data. This standard data collection format and the additional data collected for each project are included in Appendices A through D.

The amount of additional data required was a function of several factors. These included the amount of data included in the PRAM Project Plan, the nature of the decision orientation(s), and the number of weapon systems affected by the project. Additionally, although the final selection of the logistics support model used was ultimately a factor in deciding what additional data had to be collected, the collection of the common data elements listed on the form shown in Appendix A minimized the need to collect additional data elements once the final models had been selected.

This additional data collection effort proved to be a challenging task. As almost all of the previous analysis done in the PRAM Program Office was qua. .ative in nature, only one program manager within the PRAM office was familiar with current Air Force logistics support data systems. Fortunately, the data catalog under development by the SIDAC concept exploration team provided much needed assistance in the hunt for additional data. While this document was not completed during the data collection efforts of this thesis, it did provide important clues about what Air Force data systems to use to obtain support data as well as the information each data system contained.

The two Air Force data systems used to collect additional information regarding critical data elements were the various maintenance and operational data gathered by the D056 Maintenance Data Collection System and compiled by the Maintenance and Operational Data Access System (MODAS) as well as various forms of the D041 supply data system. In order to ensure the information gathered from the various Air Force data systems was accurate, the data was compared with data compiled by the Air Logistics Center (ALC) Item Management Office for the item evaluated in each project. It was during this phase of research that major discrepancies were noted from data gathered from the Air Force data systems used and the information reported by the various item managers.

This problem was especially difficult when gathering additional data for the F-15C/D Improved Aircraft Wheel Project. This difficulty first came to light when attempting to obtain failure data from MODAS. Data extracted from MODAS indicated that the current wheel was experiencing at least two to three failures per month, fleet-wide. However, a check of the D041 supply system report showed that the wheel mean time between demand (MTBD) was only one wheel every 56 months. To further confuse the issue, the Deputy

Item Manager on this wheel was carrying a MTBD of 93.71 months (35).

Unfortunately, inaccurate data was not limited just to the use of MODAS data. Further research indicated that discrepancies existed in all data systems used, including systems to gather such basic information as number of aircraft available in the active Air Force inventory (6).

This potential for inaccurate data was cause for major concern. Unfortunately, there was no easy solution to the data accuracy problem. Two major steps were taken to mitigate the consequences of inaccurate or unreliable data. First, data was verified for accuracy with the respective item managers or equipment specialists in as much as this was possible. Where the data systems conflicted with information received from the item managers, the data from the item manager was assumed to be more current and also more accurate. Second, the problem of inaccurate data dictated the importance of using a model that featured strong sensitivity analysis capability.

Gathering additional data for the AN/ALR-46/69 Signal Processor Power Supply project proved to be the most challenging task of this entire study. As stated earlier, this particular component exists in many different weapon systems, all which have rather distinct missions. It would be logical to assume, therefore, that the signal processor, and thereby the power supply of each weapon system, are subject to different levels of stress. If this is true, then the failure and demand parameters for the signal processor power supplies will vary from weapon system to weapon system, depending upon how each is used.

The data gathered from MODAS validates these assumptions. Depending on the particular weapon system, the mean time between maintenance for the signal processors varied from as little as 252 flying hours to over 4000 flying hours (30).

The variance in the magnitude of reliability and maintainability figures between weapon systems was only one symptom of a more daunting task. Of the six candidate models selected for possible use, none of them were designed for performing analyses on more than one system at a time.

Only two options were available for performing a supportability analysis of this type. The first option was to perform a separate analysis on how the power supply affected each separate weapon system and then aggregate the results. However, because of the pre-existing aggregation of supply system data on the Signal Processor Power Supply, it was determined that this method of analysis would was not practical. The only other option was to develop a methodology for aggregating each weapon system reliability and maintainability figures into a one distinct number that would represent a single weapon system.

Methodology Established for AN/ALR-46/69 Power Supply Data Aggregation

Without the development of a valid method to aggregate R&M data into a representative system, any quantitative analysis using current microcomputer logistical support models would have proven impossible. Fortunately, with considerable patience and assistance from the AFIT Center of Excellence for Reliability and Quality, a valid technique was devised to convert all the distinct data into representative aggregates. The following section details the steps taken to aggregate this information:

1. The number of annual flying hours was gathered for each weapon system. These flying hours were then totaled into a single aggregate number. The number of flying hours for each weapon system was divided by the total number of flying hours for all systems in order to come up with a weighted flying hour contribution factor for each weapon system.

2. After the flying hour contribution factor for each weapon system had been determined, the next step was to identify the appropriate reliability and maintainability information from MODAS. This task was rather challenging for two reasons. First, the work unit codes for the Signal Processor and Power Supply were different between the various weapon systems. Fortunately, within MODAS there are work unit code listings which allow you to identify the

appropriate work unit code for any component residing in any active Air Force weapon system. Second, while adequate R&M data existed for the Signal Processor work unit code, often no data was available for the power supply card. While, at first, this appeared to make the whole quantitative analysis of the Signal Processor Power Supply infeasible, a estimation of power supply failure percentages within each weapon system allowed the analysis to continue. The Systems Engineering Branch at Warner Robbins Air Logistics Center estimated that six percent of all Signal Processor failures were caused by the power supply in some weapon systems (F-16A/B/C/D; F-4D; AC-130H; MC-130E; MH-53H/J; HC-130N/P); in other weapon systems they estimated this percentage increased to eleven percent (A-10A; B-52G; B-52H; A-7D/K; AC-130A; F-4E; RF-4C) (10:2). Once the reliability values for the various Signal Processors had been identified, these estimated percentages were then used to determine the reliability values of the individual power supplies.

Before the estimated percentages could be used however, three more intermediate steps had to be taken:

a. First the appropriate "time between" variable (MTBF, MTBM) was converted into a reliability rate by using the reciprocal value.

b. Once the appropriate reliability rate was determined, this value was multiplied by the flying hour contribution factor in order to determine the weighted failure rate.

3. This weighted failure rate was then reconverted into a mean time between figure once again using the reciprocal value.

After the weighted time between reliability figure was determined for the Signal Processor of each affected weapon system, this value was then divided by the power supply failure percentage in order to estimate the time between reliability value of the Signal Processor Power Supply. This time between value was once again converted to a reliability rate.

Once this weighted power supply reliability rate had been determined for each weapon system, these weighted rates were then summed to reach an overall weighted reliability rate. This overall reliability rate was then converted back into an overall mean time between reliability factor by once again using the reciprocal of the overall reliability rate. Table 5 illustrates this process for determining mean time between failure (MTBF).

Finally, as the System Engineering Branch determined that the Signal Processor was only used between 35 to 45 percent of most mission time, a factor of .4 was used to determine the appropriate reliability and maintainability values.

Table 5

AN/ALR-46/69 Signal Processor Power Supply
Mean Time Between Maintenance (MTBM) Calculations using
Aggregate Reliability Data Methodology

Weapon System	Signal Processor MTBM	Signal Process Maint Rate	Flying Hour Factor (FHF)	Maint Rate Adjusted by FHF	Maint Rate adj by Power Supply Fail Factor	Power Supp Fail Fctr
A7D	4022.0	0.00025	0.069	0.000017	0.0000019	0.11
A7K	1798.3	0.00056	0.007	0.000004	0.0000004	0.11
A10A	2552.2	0.00039	0.208	0.000082	0.0000090	0.11
B52H	242.0	0.00413	0.033	0.000134	0.0000148	0.11
B52G	255.6	0.00391	0.063	0.000247	0.0000271	0.11
F4C	1765.3	0.00057	0.010	0.000006	0.000000	0.06
F4D	521.2	0.00192	0.063	0.000120	0.000007	0.06
F4E	226.8	0.00441	0.084	0.000372	0.0000409	0.11
F16A	319.2	0.00313	0.166	0.000519	0.000031	0.06
F16B	632.7	0.00158	0.029	0.000046	0.000003	0.06
F16C	543.5	0.00184	0.121	0.000223	0.000013	0.06
F16D	1063.7	0.00094	0.016	0.000015	0.000001	0.06
AC130A	713.4	0.00140	0.003	0.000004	0.0000004	0.11
AC130H			0.004			
HC130N	2683.8	0.00037	0.005	0.000002	0.000000	0.06
HC130P	1971.6	0.00051	0.007	0.000003	0.000000	0.06
HH53C			0.003			
MC130E	536.4	0.00186	0.007	0.000014	0.000001	0.06
MH053H			0.003			
OV10A	1246.5	0.00080	0.030	0.000024	0.000001	0.06
RF04C	240.1	0.00417	0.066	0.000274	0.0000301	0.11
MH053J			0.003			
					Pwr Sup MTBM	Pwr Sup MTBM *.40
Sig Proc Mean Time Betwn Maint->475.21					5467.13	2186.85

Using this process resulted in representative reliability and maintainability figures that were significantly different from those reported by the Engineering Systems Branch at Warner Robbins. However, it is interesting to note that the Mean Time between Maintenance calculated using this methodology came within five percent of the Mean Time between Demand calculated by the D041 supply system (5467.13 hrs using the reliability rate methodology versus 5712.1 hrs reported in the D041 factors analysis printout). Both the MTBM using MODAS and the MTBD value from the D041 factors analysis printout are calculated in the same manner.

The additional data collection efforts required for each project were directly related to the level of analysis required for the project. However, the amount of data previously collected by the various PRAM project managers also heavily influenced the amount of additional data required.

Both the F-15C/D Improved Aircraft Wheel and the C-141 VSCF System required about the same amount of additional data. Even though the C-141 VSCF System required a greater depth ofanalysis than did the F-15C/D Improved Aircraft Wheel, the C-141 VSCF System Project Manager had obtained a greater amount of data than had the F-15C/D Improved Aircraft Wheel Project Manager. In both cases however, the amount of additional data required was well over 300 percent more than the original data available for both projects.

Because of the unique nature of the form, fit, and function characteristics of the AN/ALR-46/69 Signal Processor Power Supply Improvement project, the amount of additional data required to perform an adequate microcomputer-based supportability analysis amounted to an exponential increase over the original data available. The amount of time needed to simply extract the reliability and maintainability information from MODAS exceeded two man-days. It took another week to devise a methodology that aggregated the reliability and maintainability of each weapon system into a representative data set. Without the additional data collection efforts, however, the appropriate level of supportability analysis could not have been accomplished.

Final Model Selection Process

Only two of the candidate models were selected for project analysis. But before explaining the rational for final model selection, it is important to review the criteria for model selection. Additionally, rational for non selection of any particular model will also be given. Be advised that the failure of any model to be selected for use does not necessarily indicate a faulty model, only that it did not meet the criteria established for model use. As outlined in chapter three, the criteria for model selection were as follows:

1. depth/breath of analysis required;
2. compatibility of data with model;
3. validity of model;
4. sensitivity analysis capability;
5. overall ease of use.

Non-Selected Models. Only two of the candidate models initially considered for possible use were ultimately used to accomplish the required analyses. The reasons why the two models were selected will be addressed in the sections that discuss the quantitative analysis of each project. This section will only address the candidate models that were not selected for use and the rational behind their non-selection.

The following models were not selected:

1. LAMP/LAWS. The LAMP/LAWS composite model, initially considered for use in this study, was appropriate only for use on tactical weapon systems. The only project in this study which was tactically oriented was the F-15C/D Improved Aircraft Wheel project.

However, two constraining factors of the project itself eliminated LAMP/LAWS from final model use. The first, and probably the most critical factor which eliminated the use of LAMP/LAWS was the sheer lack of data available for quantitative analysis. LAMP/LAWS required a considerable amount of data input (88 variables) in order to produce any meaningful analysis (45:183). While the extensive sensitivity analysis available would mitigate this problem in many studies, the small amount of data available for the improved F-15C/D Improved Aircraft Wheel could not be overcome by this sensitivity analysis capability. The second reason why LAMP/LAWS was not selected for use was because of the single dimensional nature of the decision orientation. LAMP/LAWS evaluates alternatives against all five R&M 2000 goals. While this is ideally a desirable trait for all trade-off analysis studies, as in the case of the F-15C/D Improved Aircraft Wheel project, there may be certain times when decision makers may desire information regarding only one particular R&M goal. In such a single dimensional study, it would not be cost effective to collect all the additional data required to run such a complex integrated model as LAMP/LAWS when other models exist that only measure the single decision orientation desired.

2. SCOPE-MOD. Initially, this model was favorably considered for accomplishing the analysis required for the C-141 VSCF System project. However, after a closer examination of the model along with two serious problems with actual model use, it was determined that the SCOPE-MOD software used by the researcher had not matured enough for performing the C-141 VSCF System analysis.

The initial evaluation of SCOPE-MOD was accomplished using the analyst's guide which came with the software. After evaluating the user documentation, it was determined that SCOPE-MOD offered some potential benefits which might prove to be advantageous to any analysis. First, SCOPE MOD already provided the analyst with a baseline data set, thereby eliminating the need for the analyst to perform this tedious and time consuming task. The second potential advantage that SCOPE-MOD offered was the potential to evaluate how changes in reliability, maintainability, and supply data affected overall system parameters, not only in terms of peacetime operating costs, but in terms of wartime sortie generating capabilities as well.

Unfortunately, these potential advantages for model use were greatly outweighed by some serious problems with operating the actual software. The first time use of the DYNAMOD portion of the software was attempted, a "floating point error" message kept appearing on the screen. After consulting both the analyst guide, as well as making a call to the SCOPE-MOD contractor in order to ensure that the fault was not because of a misunderstanding of system operation, the researcher and SCOPE-MOD vendor both concluded that there was indeed a problem with the software. When the SCOPE-MOD vendor suggested that the software be used on a microcomputer with a mathematical coprocessor, he was advised that in addition to mathematical coprocessors being unavailable for use in the PRAM office, the SCOPE-MOD analyst's guide specified that the only requirement listed for proper SCOPE-MOD utilization was an IBM compatible microcomputer with a hard disk and 256 Kilobytes of Random Accessible Memory (39:3-1). The system used by the researcher met all these requirements.

After another copy of the SCOPE-MOD software was received another attempt was made to use the model. During this attempt an additional problem surfaced with SCOPE-MOD use that made any further use undesirable. The problem encountered with the second copy of the SCOPE-MOD software was another software malfunction. After the C-141 CSD information was added to the baseline data set, an attempt was made to once again use the DYNAMOD portion of SCOPE-MOD. This attempt also failed after one day into the thirty day DYNAMOD run (DYNAMOD provides the user with a thirty day analysis of wartime sortie capability. It performs these calculations one day at a time.). This time however, instead of receiving a 'floating point' error message, the error message received was 'too many spares generated for WUC 51ABM: maximum allowable 280.' This also proved to be a fatal error, and the researcher could not continue analysis beyond this point using this second copy of the SCOPE-MOD software. The work unit coded item causing this run time error was loaded into the baseline data set by the SCOPE-MOD vendor and was a work unit code unrelated to the CSD system.

At this point further SCOPE-MOD use was not considered. While further discussions with the contractor may have eventually eliminated all software problems, the ability of SCOPE-MOD to adequately accomplish the required analysis was questionable. Rather than continue with further attempts to use the SCOPE-MOD software, the researcher used another model more appropriate to the level of analysis required by the C-141 VSCF System project.

3. LSC version 2.0. Initially, this model was considered for its capability to model logistics support costs. Additionally, LSC did not require an inordinate amount of input data.

For all its potential advantages, however, LSC lacked a couple of features which made its use inappropriate for this study. First, LSC was designed to model logistics support cost. As such, the model was unable to include a variety of specific PRAM project acquisition costs. LSC also has very limited sensitivity analysis capability. Because of extensive data uncertainty experienced during the project data collection process, this became a limiting factor. Another disadvantage of LSC was its inability to perform alternative cost comparisons on-line. Any comparisons of an existing system or sub-system with a proposed alternative would have to be done manually, after separate cost outputs had been generated for each alternative. This last limitation of LSC was minor, but was another factor which eliminated its use in this study.

4. LCCHPC. The capability of this microcomputer version of LCCH to capture all appropriate LCC costs lead to its inclusion as a candidate model during the initial model survey. However, the serious difficulty was encountered in setting up data input files.

The microcomputer version of LCCH did not contain any provisions for automatic development of input data files.

The model required that the user develop data entry files using a ASCII text editor. While the documentation did provide examples of how each data file was to be developed, it was the user's responsibility to determine exactly where each value was to be placed in the text file. This entire procedure was complex and cumbersome. It ultimately caused the researcher to abandon any efforts to use this model.

Quantitative Analysis Using Selected Models

Only two of the candidate models surveyed provided analysis capabilities that matched the predetermined analysis levels required for each of the three projects. The Statistically Improved Life Cycle Cost (SILCC) model was the most relevant model for performing quantitative analysis for the F-15C/D Improved Aircraft Wheel project. The Cost Analysis and Strategy Assessment Model was found to provide the required analysis capabilities for both the C-141 VSCF System project and the AN/ALR-46/69 Signal Processor Power Supply project. The rational for selecting each model is described in the subsequent sections detailing the results of the quantitative analysis performed for each project, along with the limitations of each model. SILCC limitations are discussed immediately following the section detailing the quantitative analysis of the F-15C/D Improved Aircraft Wheel project. However, as CASA was used to perform the quantitative analysis of the two remaining projects, a description of its limitations does not occur until after the discussion of the AN/ALR-46/69 Signal Processor Power Supply analysis.

F-15C/D Improved Aircraft Wheel

Rational for Using SILCC. As previously described. the decision orientation for the F-15C/D project was one dimensional. Because of the higher unit cost of the proposed RST wheel, along with the adequate reliability of the existing 2014 wheel, this project would be successful only if operational and support costs of the proposed wheel were significantly lower than the existing wheel.

Beside the need to examine the life cycle costs, the amount of data available for any quantitative analysis was not only limited, but also questionable in its accuracy. The integrity of the wheel information available from MODAS was suspect, because of the extremely high failure rates reported by MODAS, which contradicted by the data available from the D041 factors analysis printout as well as data from the landing gear equipment specialist at Ogden ALC.

The model most suited for analysis of this project would ideally be a LCC model that allowed the user to perform a relatively uncomplicated analysis using the limited amount of data available. Because of the uncertainty of many of the key data elements of this project, this model would also have strong sensitivity analysis capabilities.

The SILCC model provided both of those capabilities. SILCC adequately accomplished the LCC analysis using only 28 variables for each alternative. In addition to its ability to use the limited amount of data available, the model included the capability to determine the sensitivity of each variable to a percentage change in its value. Not only did SILCC provide the capability to rapidly determine the sensitivity of any single variable to a changes in its value, it also provided the researcher with a function that rank ordered the sensitivity of every variable in the model. This feature proved to be especially useful because it immediately displayed those variables that were the most sensitive to changes in value, thereby eliminating the time often spent trying to manually determine the degree of variable sensitivity.

An important characteristic of SILCC that was not offered by any other model surveyed was the extensive use it made of existing Air Force data systems for model input. Indeed, the main premise of developing SILCC was that "its data support should be met entirely by standard information systems currently existing in the Air Force" (37:5). The user documentation listed the primary Air Force source for every data element used by the model, often supplementing the data system reference with a specific point of contact (37:3-29). Additionally, SILCC documentation not only acknowledged the possibility of problems with data accuracy, but provided two options for dealing with this problem. The first methodology was through the capability to provide the decision maker with a statistical confidence level of LCC totals and each output variable. This was accomplished by allowing the researcher to specify a probability that input parameter mean will vary from its actual value, and then used descriptive statistical techniques to calculate the range of the given parameter value. The second methodology for dealing with data uncertainty was through the use of its extensive sensitivity analysis previously mentioned.

Ease of data entry, the capability to provide on-line alternative comparisons, and the unambiguous output reports generated by SILCC were three other powerful features that increased its value. Data entry for each alternative was accomplished on a single screen. After data entry was completed, data files were saved through a single keystroke action. SILCC ability to provide on-line LCC comparisons between alternatives allowed for the researcher to quickly examine how any changes in one of the input variables affected the difference in total LCC between the two alternatives. Finally, in addition to the many computational output reports provided by SILCC, it provided the researcher with a limited number of output graphs highlighting how total LCC costs were affected by changes in four key variables (MTBD, MTBR, Depot Maintenance Manhour Costs, and Base Maintenance Manhour Costs).

Analysis Using SILCC. Using all the data from the F-15C/D Improved Aircraft Wheel for the baseline analysis (see Appendix E and F for initial data inputs), the initial results shown in Table 6 illustrated that only $7522 dollars separated the two alternatives; the delta being only .22 percent of total LCC over a 20 year period. After performing a ranked sensitivity analysis of all variables, it was noted that the base no repair this station (NRTS) for the wheel ranked fourth on the sensitivity analysis report for both the existing and proposed alternatives. Of the three variables listed before the NRTS rate, only the mean time between removal (MTBR) data element was a variable which might have some uncertainty associated with it. However, because of previous conversations with the Deputy Item Manager at Ogden and the PRAM project manager, the original five percent NRTS rate became immediately suspect after the initial LCC comparisons were made and a ranked variable sensitivity analysis report was generated. A closer examination of the input data revealed that the number of annual base wheel repairs generated was only about 30 percent of total annual wheel repairs, with depot repair accounted for the remaining 70 percent (162 annual base repairs versus 533 annual depot repairs). A second LCC comparison was made using these repair percentages as base repair this station (RTS) and base NRTS rates. As Table 7 illustrates, the large change in the NRTS rates had a

Table 6

Results of F-15C/D Improved Aircraft Wheel
Baseline Analysis Using Original NRTS Rates

17:43:02 07-15-89

Life Cycle Cost Comparison

Labels		2014alum		newrst	Delta
CNLV	-	.950	-	.950	.00 %
BSTK	-	5.	-	3.	-40.00 %
DSTK	-	3	-	2.	-33.33 %
QCS	-	35.	-	24.	-31.43 %
BMMH	H	261.	H	174.	-33.33 %
DMMH	H	187.	H	125.	-33.33 %
PMSH	H	14.	H	9.	-33.33 %
DEVC	$	0.	$	0.	.00 %
SYSI	$	0.	$	846500.	9999.99 %
SEC	$	0.	$	0.	.00 %
BSC	$	372900.	$	257400.	-30.97 %
BMHC	$	548791.	$	365860.	-33.33 %
BMMC	$	19850.	$	13233.	-33.33 %
DSC	$	20340.	$	15600.	-23.30 %
DMHC	$	80247.	$	53498.	-33.33 %
DMMC	$	428621.	$	154354.	-63.99 %
SDTC	$	573521.	$	382347.	-33.33 %
CSC	$	237300.	$	187200.	-21.11 %
IMCC	$	236232.	$	236232.	.00 %
LCC	$	2517802.	$	2512225.	-.22 %
AVE/YR	$	125890.	$	125611.	-.22 %

Table 7

Results of F-15C/D Improved Aircraft Wheel
Baseline Analysis Using Adjusted NRTS Rates

17:46:35 07-15-89

Life Cycle Cost Comparison

Labels		2014alum		newrst	Delta
CNLV	-	.950	-	.950	.00 %
BSTK	-	3.	-	2.	-33.33 %
DSTK	-	13.	-	8.	-38.46 %
QCS	-	35.	-	24.	-31.43 %
BMMH	H	180.	H	120.	-33.33 %
DMMH	H	1454.	H	969.	-33.33 %
PMSH	H	5.	H	3.	-33.33 %
DEVC	$	0.	$	0.	.00 %
SYSI	$	0.	$	846500.	9999.99 %
SEC	$	0.	$	0.	.00 %
BSC	$	223740.	$	171600.	-23.30 %
BMHC	$	378602.	$	252401.	-33.33 %
BMMC	$	6544.	$	4363.	-33.33 %
DSC	$	88140.	$	62400.	-29.20 %
DMHC	$	624145.	$	416097.	-33.33 %
DMMC	$	3333719.	$	1200528.	-63.99 %
SDTC	$	4460719.	$	2973813.	-33.33 %
CSC	$	237300.	$	187200.	-21.11 %
IMCC	$	236232.	$	236232.	.00 %
LCC	$	9589140.	$	6351133.	-33.77 %
AVE/YR	$	479457.	$	317557.	-33.77 %

dramatic effect on the total LCC difference between the current and proposed wheel. With a base NRTS rate of 70 percent, the proposed RST wheel LCC costs were about $3.2 million dollars less than the current 2014 wheel (a 33.77% delta). Because the number of actual repairs accomplished was a more accurate figure than the original NRTS rates reported by both the D041 and the item manager, these LCC figures became the baseline results for the F-15C/D analysis using SILCC.

Higher NRTS rates also had significant effects on total LCC differences, although additional increases in percent of change were not nearly as great. A base NRTS of 95 percent produced a total LCC cost difference of over $4.6 million dollars (a 36.9 percent difference). Increasing the base NRTS rate to 100 percent, produced a total LCC cost difference of over 5 million dollars (a 37.33 percent delta). In each case, the RST proposal showed significant reductions in operational and support costs.

In addition to examining the sensitivity analysis of the NRTS rates, the values of the ten variables identified as most sensitive to change were varied by at least 25 percent. Table 8 shows the effect of each change on total LCC. While many changes had great effect on the absolute value of LCC costs, most of the deltas between the two proposals were only affected by about 3 to 4 percent.

Table 8

Results of F-15C/D Improved Aircraft Wheel
Sensitivity Analysis Using the
Ten Most Sensitive Variables Identified by SILCC

Variable and Sensitivity Ranking	Percent Change	2014 LCC	RST LCC	Delta
PIUP (1)	25% decrease	$7268131	$5033475	30.75%
MTBR (2)	25% decrease (RST)	$9589140	$8021467	16.35%
AOH (3)	25% decrease	$7327188	$5092533	30.50%
AOH (3)	25% increase	$11851090	$7601933	35.85%
NRTS (4)	25% increase	$11645530	$7417434	36.31%
NRTS (4)	25% decrease	$7464948	$5191232	30.46%
PSC (5)	25% increase	$10704320	$7094586	33.72%
DMC (7)	25% increase (RST)	$9589140	$6651265	30.64%
SYSI (8)*	25% increase (RST)	$9589140	$6562758	31.56%
SYSI (8)*	50% increase (RST)	$9589140	$6774383	29.35%
SYSI (8)*	100% increase (RST)	$9589140	$7197633	24.94%
DLR(8,10)**	25% increase	$9738051	$6450407	33.76%
DMH(9,11)***	25% increase	$9745177	$6455157	33.76%
UC(10,9)****	25% increase (RST)	$9589140	$6456433	32.67%
UC(10,9)****	50% increase (RST)	$9589140	$6561733	31.57%

Definitions

PIUP - Projected Inventory Usage Period
MTBR - Mean Time Between Removal
AOH - Annual Operational Hours
NRTS - Base No Repair This Station
PSC - Packing and Shipping Costs
DMC - Depot Material Costs
SYSI - System Investment Costs
DLR - Depot Labor Rate/Manhour
DMH - Depot Maintenance Manhours
UC - Unit Costs

NOTES

* SYSI sensitivity analysis ranked 8th for RST alternative only; 2014 alternative had no SYSI costs
** DLR sensitivity analysis ranked 8th for 2014 alternative; 10th for RST alternative
*** DMH sensitivity analysis ranked 9th for 2014 alternative; 11th for RST alternative
**** UC sensitivity analysis ranked 10th for 2014 alternative; 9th for RST alternative

However two variables having a large impact of total LCC were (a) the effect of increasing the development costs of the proposed RST wheel and (b) a decrease in mean time between removal (MTBR). As Table 8 illustrates, a 25 percent reduction in MTBR time of the proposed RST wheel would result in only about a $1.5 million dollar LCC savings, which is a significant reduction from the baseline savings. LCC comparisons were made with the RST development costs increased to over 50 and 100 percent of the proposed RST price in order to examine how RST development overruns affected the feasibility of the project. Table 8 also shows an 100 percent increase in RST development costs reduces the total LCC savings of the proposed RST wheel to about $2.4 million dollars.

Findings. The baseline analysis (using a NRTS rate of 70 percent) demonstrated that the total LCC cost savings of the using the RST wheel as opposed to the current 2014 wheel were about $3.2 million dollars. This demonstrated a positive return on investment of about 3.8 to 1, a figure significantly lower than the original PRAM Project Plan figure of 12.6 to 1.

Analysis showed that one of the most important variables affecting the differences in LCC between the two alternatives was the base NRTS rates. The less capability that the base level maintenance has to repair the wheel, the more attractive the proposed RST wheel alternative becomes.

This was an important result of the analysis because, although the NRTS rates reported in the D041 were only five percent of all repairs, the Landing Gear Deputy Item Manager at Ogden ALC stated that almost all work done on F-15C/D wheels was performed at the depot maintenance level (35). Indeed, if the base level NRTS rates were 100 percent, the RST LCC savings would be over $5 million dollars, increasing the project ROI to over 5.9 to 1.

The other significant variable affecting project cost savings was wheel MTBR. The RST wheel proposed to improve wheel MTBR by over 50 percent, to over 1002 hours. If this proposed improvement was understated, the cost savings would be reduced to about $1.5 million dollars, thereby reducing the project ROI by to approximately 1.9 to 1.

The most important finding of this analysis is was that although SILCC reported LCC savings significantly lower than reported by the initial PRAM Project Plan, an extensive amount of sensitivity analysis revealed that this project would still provide substantial cost savings under many changing assumptions. Only if the inaccurate NRTS data was assumed correct would the cost savings be marginal.

SILCC Limitations

As useful as SILCC was in preforming this analysis, it was not without its limitations. Perhaps the most serious limitation of SILCC was its inflexibility to handle changes to spares provisioning policy. SILCC calculates base, depot, and condemnation spares using optimal spares provisioning formula based on manipulating system peak monthly operating hours (POH), pipeline time, mean time between demand (MTBD), and the number of weapon system basing locations (37:38). Using the baseline data set, SILCC estimated that between base, depot, and condemnation spares requirements, the 2014 would require 86 spares versus 54 spares required for the RST option. However, the Landing Gear Division at Ogden ALC has a current spares inventory of 1080 main landing gear wheels, and the new RST proposal suggested only a need for about 235 spares (43:8). While one might debate the necessity of keeping such a large supply of spares, especially for the 2014 wheel, the fact remains that, for whatever reason, the policy of stocking 1080 spares is current depot maintenance policy. SILCC has no mechanism to adjust the number of base level, depot level, or condemnation spares. In order to determine the exact LCC for both alternatives, the analyst would have to determine the cost effects of the actual and proposed spares provisioning policies and manually add the cost of any additional spares acquisition to the LCC results generated by SILCC. Fortunately, because all needed spares had already been procured, this problem had little effect on the overall analysis.

SILCC was also quite limited in its capability to model several categories of LCC costs. Systems and Development

Costs could only be entered as throughput costs. Support Equipment Costs could also only be entered as throughput costs. Additionally, SILCC did not have any capabilities to model recurring support equipment costs, documentation costs, or training costs. While none of these limitations had a direct impact on the F-15C/D Improved Aircraft Wheel Study, had it been important to capture any of these LCC categories, it would not have been possible to complete the analysis.

C-141A/B VSCF System

Rational For Using CACA. The C-141A/B VSCF System project called for the use of more sophisticated analysis capabilities than those available from SILCC. The decision orientation required an analysis of reliability and life cycle costs. Additionally, the relatively large amount of data available could not be adequately modeled though the use of SILCC or any other model surveyed.

Because of the unique nature of a wide variety of costs included in the C-141A/B VSCF System project study, a model was needed which provided a certain degree of flexibility, in order to capture these costs. There were several acquisition costs which were difficult to lump together simply as throughput, although this task could have been accomplished. More importantly, however, was the need to capture associated maintenance costs which occurred periodically and at unequal intervals throughout the study time period. Under the existing CSD alternative, CSD failure may or may not require repair of the electrical generator associated with it. The only generator repair data available for analysis was the number of generators repaired annually and the total annual generator repair cost. It was important that a model be able to somehow handle this unique repair cost.

The Cost Analysis and Strategy Assessment (CASA) model was the only model with the capability to handle these unique requirements. It had several categories of acquisition costs which allowed for more accurate modeling of the proposed VSCF acquisition costs. Additionally, it allowed the annual generator repair costs to be included in the analysis.

CASA had some other features which facilitated quantitative analysis of the C-141A/B system. The model permitted rapid entry of a large amount of data through a series of menu driven input screens. As with SILCC, it allowed quick on-line cost comparisons to be made after any number of variable changes had been made. This feature allowed the researcher to perform a number of sensitivity analyses on several input variables. Additionally, the ability for the model to assess an infinite number of both of inflation and discount rates gave the researcher the opportunity to present decision makers with a more accurate assessment of true operational and support costs of the alternatives being considered.

Besides the great flexibility it demonstrated in performing this particular analysis, CASA offered the researcher a unique capability to quantify project risk. CASA allowed the researcher to estimate a number of possible distributions of unit costs, MTBF, and mean time to repair (MTTR), then use these distributions in performing up to 1000 iterations of a Monte Carlo simulation module appropriately named RISKMC. The RISKOUT module then displays the 1-100 percent LCC probabilities for the alternative being analyzed, and calculates the strength of the simulation using both the alpha and beta statistical tests.

Although the data input module of CASA contained over 34 categories of information and 77 separate data entry screens, another capability of CASA that added tremendously to its flexibility was its ability to work off a limited data set and still produce workable results, in contrast to many microcomputer logistics support models that will not execute unless certain default parameters are entered as inputs. However, when using CASA, with a few critical exceptions, if parameters must be zeroed out because of nonavailability of data, those parameters are ignored when CASA performs LCC calculations.

A final reason why CASA was chosen to accomplish this analysis was because of the ever growing acceptance of model use within both the Air Force and the DOD supportability community. Additionally, several independent studies have validated both the model's accuracy and statistical robustness (25:35, 33:335, 21:12).

<u>Analysis Using CASA</u>. The data elements from the C-141A/B VSCF System project data analysis worksheet were used as data sets for baseline analysis (See Appendix I and J for model inputs). As Table 9 illustrates, the total LCC of the proposed VSCF system was slightly more than $78.3 million dollars above the total LCC costs of the existing CSD system (a 102.2 percent delta). While the VSCF system demonstrated a significant savings in operational and support cost over the existing CSD system (slightly more than $52.8 million dollars), the considerable front end development and implementation costs of the proposed VSCF system (over $136.2 million dollars) negated the estimated operational and support cost reductions of the VSCF system.

While CASA allowed the researcher to change any number of input variables and examine the effect of the change on each alternative LCC, its SENSE module let the researcher perform direct sensitivity analysis of unit cost, MTBF, and MTTR by inputing desired percentage changes to the UC, MTBF, or MTTR baseline variable values. Table 10 highlights the results of this sensitivity analysis for the VSCF alternative.

Table 9

Results of C-141A/B CSD vs VSCF Baseline Analysis

COST COMPARISON (1985 DOLLARS x 1000) 07-04-89

*** TOTALS OVER ALL YEARS ***

Base: C-141 Constant Speed Drive
Alternative: C141 Variable Speed Constant Frequency Drive

	Total Base	Total Alternative	Diff	%Diff
ACQUISITION COSTS				
TOOLING AND T.E.	.0	.0	.0	.0
START UP	.0	.0	.0	.0
SYSTEM ACQUISITION	.0	108199.0	108199.0	.0
SHIPPING CONTAINERS	.0	.0	.0	.0
PRE-PROD ENG CHANGES	.0	1600.0	1600.0	.0
PRE-PROD REFURBISH	.0	.0	.0	.0
INSTALLATION	.0	16260.0	16260.0	.0
SUPPORT EQUIPMENT	.0	.0	.0	.0
HARDWARE SPARES	5051.2	3203.5	-1847.7	-36.6
SPARES REUSABLE CONT	.0	.0	.0	.0
INITIAL TECH DATA	.0	.0	.0	.0
INITIAL TRAINING	.0	.0	.0	.0
TRAINING DEVICES	.0	.0	.0	.0
NEW FACILITIES	.0	.0	.0	.0
INITIAL ITEM MGMT	.0	.0	.0	.0
MISC ACQ COSTS	.0	7000.0	7000.0	.0
WARRANTY	.0	.0	.0	.0
TOTAL ACQ COST	5051.2	136262.5	131211.3	2597.6
OPERATION & SUPPORT COSTS				
OPERATION LABOR	.0	.0	.0	.0
REPAIR LABOR	5868.7	2340.1	-3528.6	-60.1
SUPPORT EQUIP MAINT	.0	.0	.0	.0
RECURRING TRAINING	.0	.0	.0	.0
REPAIR PARTS AND MTL	45861.6	13425.8	-32435.8	-70.7
CONSUMABLES	.0	.0	.0	.0
CONDEMNATION SPARES	.0	.0	.0	.0
TECH DATA REVISIONS	.0	.0	.0	.0
TRANSPORTATION	7695.2	3068.5	-4626.7	-60.1
RECURRING FACILITIES	.0	.0	.0	.0
RECURRING ITEM MGMT	.0	.0	.0	.0
CONTRACTOR SERVICES	.0	.0	.0	.0
ENGINEERING CHANGES	.0	.0	.0	.0
MISC O & S COSTS	12225.0	.0	-12225.0	-100.0
TOTAL O&S COST	71650.5	18834.4	-52816.1	-73.7
TOTAL COST	76701.7	155096.9	78395.2	102.2

Table 10

Sensitivity Analysis Examining LCC Effects of Changing VSCF MTBF, MTTR, and Unit Costs While Holding CSD Costs Constant (in thousands of dollars)

Variable	Percent of VSCF Baseline*	CSD LCC	VSCF LCC	Diff in both Dollars and Percentage	
MTBF	25	$76701.6	$217559.8	$140858.2	(183.6%)
MTBF	50	$76701.6	$175942.7	$99241.1	(129.4%)
MTBF	75	$76701.6	$162045.4	$85343.8	(111.3%)
MTBF	100	$76701.6	$155096.8	$78395.2	(102.2%)
MTBF	125	$76701.6	$150957.5	$74255.9	(96.8%)
MTBF	150	$76701.6	$147328.7	$70627.1	(92.1%)
MTBF	225	$76701.6	$142621.8	$65920.2	(85.9%)
MTBF	300	$76701.6	$140030.5	$63328.9	(82.6%)
MTTR	25	$76701.6	$153341.7	$76640.1	(99.9%)
MTTR	50	$76701.6	$153926.8	$77225.2	(100.7%)
MTTR	75	$76701.6	$154511.8	$77810.2	(101.4%)
MTTR	100	$76701.6	$155096.8	$78395.2	(102.2%)
MTTR	125	$76701.6	$155681.9	$78980.2	(102.9%)
MTTR	150	$76701.6	$156226.9	$79525.3	(103.7%)
MTTR	225	$76701.6	$158022.0	$81320.4	(106.0%)
MTTR	300	$76701.6	$159777.1	$83075.5	(108.3%)
UC	25	$76701.6	$71545.0	$-5156.6	(-6.7%)
UC	50	$76701.6	$99395.6	$22694.0	(29.6%)
UC	75	$76701.6	$127247.9	$50546.3	(65.9%)
UC	100	$76701.6	$155096.8	$78395.2	(102.2%)
UC	125	$76701.6	$182945.4	$10643.8	(138.5%)
UC	150	$76701.6	$210801.4	$134099.8	(174.8%)
UC	225	$76701.6	$294347.5	$217645.9	(283.8%)
UC	300	$76701.6	$377908.5	$301206.9	(392.7%)

* VSCF MTBF Baseline = 4000 hrs
VSCF MTTR Baseline = 16 hrs
VSCF UC Baseline = $74,500.00

Sensitivity analysis was also conducted for the unit cost, MTBF, and MTTR of the existing CSD alternative. Because the existing values of these parameters were considered relatively "hard" data, in contrast to the untested data presented for the VSCF alternative, the CSD baseline values were only varied by a range of 25 to 125 percent. Table 11 contains the results of the CSD analysis.

Besides the sensitivity analysis conducted for the UC, MTBF, and MTTR, for each alternative, many other maintenance variables were changed to determine their effect on costs. These changes included decreasing the years of useful system life, increasing and decreasing the number of monthly operating hours, and decreasing the base NRTS rate. Additionally, the effects of inflation and discounting on overall Life Cycle Costs were examined. Table 12 highlights the results of these sensitivity analyses.

In addition to performing the above sensitivity analysis, risk analysis was performed on the VSCF alternative, using the RISKMC module. The risk analysis was performed in an attempt to account for the "soft" VSCF data, as well as to demonstrate the risk analysis capabilities of CASA. The RISKMC module is a Monte Carlo simulation program which allows the researcher to establish both a value range for Unit Costs, MTBF, and MTTR, and select probability distributions for the chosen values. After the values of each

Table 11

Sensitivity Analysis Examining LCC Effects of Changing CSD MTBF, MTTR, and Unit Costs While Holding VSCF Costs Constant (in thousands of dollars)

Variable	Percent of CSD Baseline*	VSCF LCC	CSD LCC	Diff in both Dollars and Percentage	
MTBF	25	$155096.8	$267185.0	$112088.2	(72.3%)
MTBF	50	$155096.8	$140035.7	$-15061.1	(-9.7%)
MTBF	75	$155096.8	$97833.0	$-57263.8	(-36.9%)
MTBF	100	$155096.8	$76701.6	$-78395.2	(-50.5%)
MTBF	125	$155096.8	$64034.8	$-91062.0	(-58.7%)
MTTR	25	$155096.8	$72300.1	$-82796.7	(-53.4%)
MTTR	50	$155096.8	$73767.1	$-81329.7	(-52.4%)
MTTR	75	$155096.8	$75234.5	$-79862.3	(-51.5%)
MTTR	100	$155096.8	$76701.6	$-78395.2	(-50.5%)
MTTR	125	$155096.8	$78168.8	$-76928.0	(-49.6%)
UC	25	$155096.8	$72913.2	$-82183.6	(-53.0%)
UC	50	$155096.8	$74176.0	$-80920.8	(-52.2%)
UC	75	$155096.8	$75438.8	$-79658.0	(-51.4%)
UC	100	$155096.8	$76701.6	$-78395.2	(-50.5%)
UC	125	$155096.8	$77964.6	$-77150.2	(-49.7%)

* CSD MTBF Baseline = 1595 hrs
CSD MTTR Baseline = 16 hrs
CSD UC Baseline = $60,133.76

Table 12

Results of C-141A/B VSCF System Sensitivity Analysis for Selected Variables Using CASA (in thousands of dollars)

Variable	Percent Change	CSD LCC	VSCF LCC	Delta
Useful Life	25% decrease	$56639.4	$149823.2	164.5%
System Op Hours	25% increase	$92521.9	$160327.5	73.3%
System Op Hours	25% decrease	$60821.3	$149046.6	145.1%
NRTS rate	25% decrease	$60821.3	$145852.5	139.8%
MTTR	300% increase	$88439.0	$159777.2	80.7%
Inflation	5% per year	$148929.9	$180829.7	21.4%
Inflation and Discount rate	5%Inf/10%Disc	$46196.9	$140944.8	205.1%

variable and their probability distributions have been selected, RISKMC allows the researcher to choose between 50 and 1000 iterations of the simulation. After the number of iterations is chosen, RISKMC "fits" the values chosen to the probability distribution selected and the number of iterations chosen. The resulting output is a prediction of LCC probabilities based on the probability distribution selected and the number of iterations chosen.

For risk analysis of the C-141 VSCF alternative, Table 13 shows the parameters selected for unit cost, MTBF, and MTTR. The unit cost of the VSCF was varied from its proposed price to a value representing a 25 percent cost increase. The MTBF value was varied in order to capture a 25 percent decrease to 50 percent increase. Finally, the MTTR value was varied to capture a 25 percent decrease to a fifty

Table 13

Parameters Selected for C-141A/B VSCF Risk Analysis

Variable	Distribution	Lowest Value	Highest Value
Unit Cost	Uniform	$74,500	$93,125
MTBF	Uniform	3000 hrs	6000 hrs
MTTR	Uniform	32 hrs	64 hrs

percent increase in the depot maintenance hours required to repair the VSCF. As the probability distribution of this proposed data was unknown, the researcher chose to use a uniform distribution.

The maximum number of iterations (1000) was chosen for the Monte Carlo Simulation in an effort to increase its statistical significance. Figure 5 indicates the results of the C-141A/B VSCF risk analysis.

Findings. The baseline LCC comparison indicated that implementing the VSCF alternative would increase LCC costs by about 102.2 percent of the existing CSD system over an estimated 25 year useful life of the C-141A/B fleet. Additionally, the calculated ROI of this project was significantly less than one.

The analysis performed by using CASA indicated that the initial analysis done by the PRAM staff had overestimated the ROI of the VSCF alternative. The cost/benefits calculations performed by PRAM staff analysis estimated that the C-141A/B project ROI was .51 to 1. The baseline analysis of the VSCF alternative using CASA estimated a ROI of .34 to 1.

The sensitivity analysis capabilities of CASA showed that except for a couple of extreme cases, the existing CSD alternative proved to be the more viable cost option. Under all scenarios examined, the only times that the VSCF option proved to be the more viable alternative was when the VSCF MTBF was obtainable and the current CSD MTBF was overestimated by 75 percent, or if the proposed VSCF unit cost

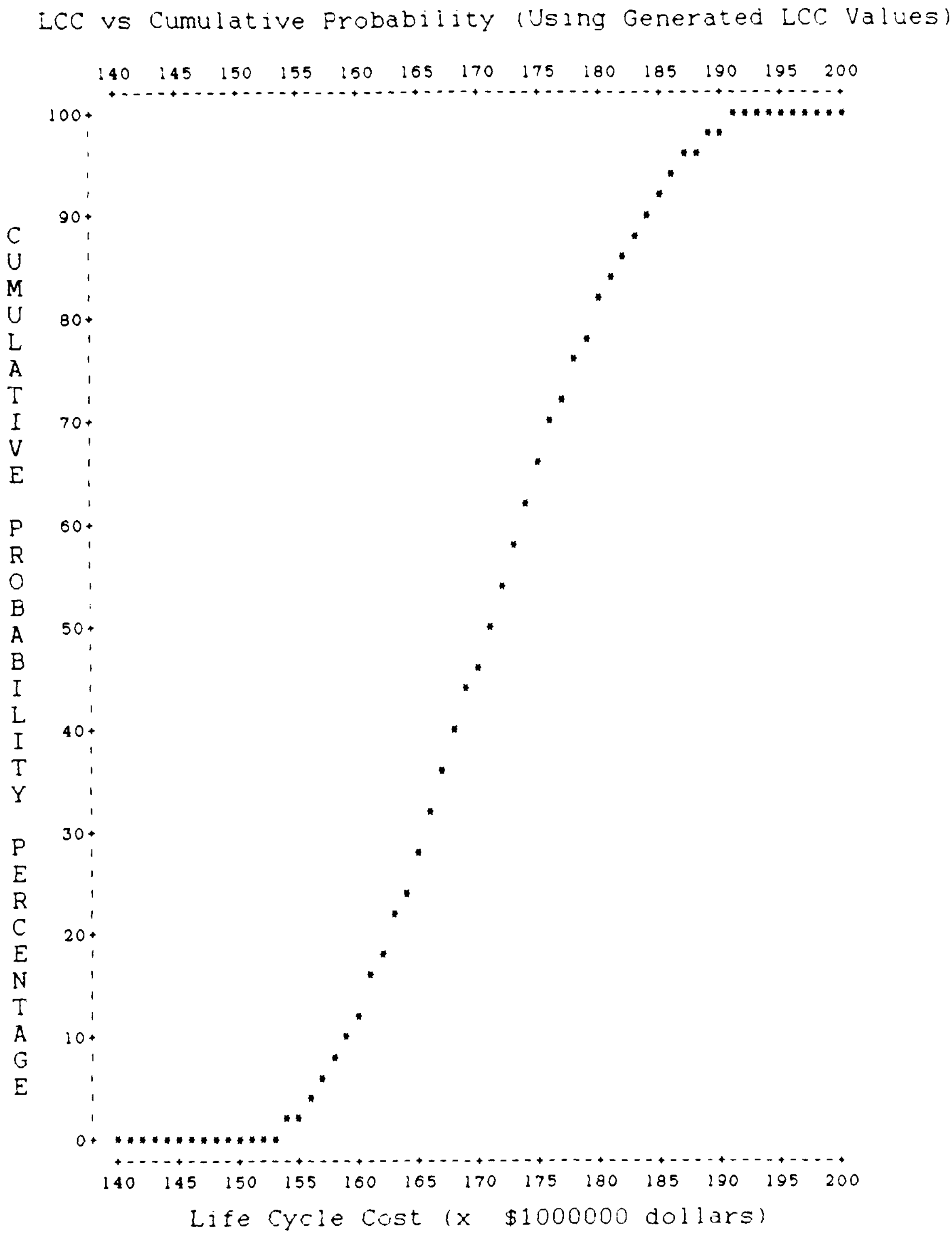

Figure 5. Cumulative LCC Probability Curve for C-141A/B VSCF Alternative

was reduced by 75 percent. The likelihood of either of these events occurring could occur appeared remote.

The baseline delta between the two alternatives became even larger when a conservative five percent inflation rate and the current accepted Department of Defense (DOD) discount rate of 10 percent were applied to the life cycle costs of both alternatives. With both of these factors calculated into the study, the VSCF ROI became .21 to 1.

Finally, by performing a limited risk analysis using the RISKMC module of CASA, the researcher found VSCF costs varying between $155 million dollars and $190 million dollars. Additionally, using the risk analysis parameters listed in Table 13, the RISKMC estimated that there was about .95 probability of VSCF costs reaching $185 million dollars.

Through having performed the initial baseline comparison, extensive sensitivity analysis, and a limited risk analysis, the quantitative analysis showed that under a wide variety of assumptions, the VSCF did not prove to be a cost effective option, even though it improved reliability by over 300 percent. The VSCF system may indeed provide additional reliability, but the extensive quantitative analysis performed suggested that it may not be worth the large acquisition cost.

AN/ALR-46/69 Signal Processor Power Supply

Rational For Using CASA. As mentioned earlier, the additional data collection effort for this project proved to be particularly challenging. As the AN/ALR-46/69 Radar Warning Receiver was in use on more than 17 different weapon systems, subjecting the Signal Processor Power Supply to several different stress levels, only two analysis options seemed to be available:

1. Perform separate analysis for each weapon system.

2. Formulate a methodology to aggregate the necessary reliability and maintainability data necessary to provide representative data inputs to a particular model.

The difficulty with choosing the first alternative for the AN/ALR-46/69 Signal Processor Power Supply project was that existing Air Force inventory management data systems aggregate the only information available concerning maintenance repair cycle time, mean time to repair, mean time between demand, and a host of other reliability and maintainability information. The researcher was unable to find enough distinct data to perform the Signal Processor Power Supply analysis for each separate weapon system.

The only choice left to the researcher, if any analysis was to be accomplished, was to aggregate the reliability and maintainability data. A methodology was formulated to successfully accomplish this task with a fair amount of accuracy.

In addition to the desirable reliability and maintainability characteristics mentioned in the previous C-141A/B analysis, CASA was chosen as the model to use for this project because it was determined that this model had the greatest capability to handle this aggregated data. Additionally, CASA determines average number of operating systems per location by dividing the total number of weapon systems using this system by the number of operating locations. While this method of determining operating systems per location may overestimate or underestimate the absolute number of operating systems at any given location, it greatly facilitated data entry and was acceptable for the purposes of this study.

Analysis Using CASA. As with the previous two projects, the AN/ALR-46/69 project data analysis worksheet provided the data required for the baseline analysis. (See Appendices J and I). Table 14 illustrates the initial analysis results. It reveals that operational and support cost savings of the improved version of the Signal Processor Power Supply to be $2060.6 million dollars over the 10 year period.

As with the C-141 VSCF System project, the SENSE module of CASA was used to perform sensitivity analysis of Unit Cost, MTBF, and MTTR for each alternative. Additionally,

Table 14

Results of AN/ALR-46/69 Signal Processor Power Supply Baseline Analysis

COST COMPARISON (1985 DOLLARS x 1000) 07-06-89

*** TOTALS OVER ALL YEARS ***

Base: Existing AN/ALR-46/69 Power Supply
Alternative: Improved AN/ALR-46/69 Power Supply

	Total Base	Total Alternative	Diff	%Diff
ACQUISITION COSTS				
TOOLING AND T.E.	.0	.0	.0	.0
START UP	.0	.0	.0	.0
SYSTEM ACQUISITION	.0	.0	.0	.0
SHIPPING CONTAINERS	.0	.0	.0	.0
PRE-PROD ENG CHANGES	.0	300.0	300.0	.0
PRE-PROD REFURBISH	.0	.0	.0	.0
INSTALLATION	.0	.0	.0	.0
SUPPORT EQUIPMENT	.0	.0	.0	.0
HARDWARE SPARES	145.6	39.0	-106.6	-73.2
SPARES REUSABLE CONT	.0	.0	.0	.0
INITIAL TECH DATA	.0	.0	.0	.0
INITIAL TRAINING	.0	.0	.0	.0
TRAINING DEVICES	.0	.0	.0	.0
NEW FACILITIES	.0	.0	.0	.0
INITIAL ITEM MGMT	.0	.0	.0	.0
MISC ACQ COSTS	.0	.0	.0	.0
WARRANTY	.0	.0	.0	.0
TOTAL ACQ COST	145.6	339.0	193.4	132.8
OPERATION & SUPPORT COSTS				
OPERATION LABOR	.0	.0	.0	.0
REPAIR LABOR	1835.1	72.9	-1762.2	-96.0
SUPPORT EQUIP MAINT	.0	.0	.0	.0
RECURRING TRAINING	.0	.0	.0	.0
REPAIR PARTS AND MTL	276.4	81.8	-194.6	-70.4
CONSUMABLES	2.8	.8	-2.0	-71.4
CONDEMNATION SPARES	.0	.0	.0	.0
TECH DATA REVISIONS	.0	.0	.0	.0
TRANSPORTATION	144.6	42.8	-101.8	-70.4
RECURRING FACILITIES	.0	.0	.0	.0
RECURRING ITEM MGMT	.0	.0	.0	.0
CONTRACTOR SERVICES	.0	.0	.0	.0
ENGINEERING CHANGES	.0	.0	.0	.0
MISC O & S COSTS	.0	.0	.0	.0
TOTAL O&S COST	2258.9	198.3	-2060.6	-91.2
TOTAL COST	2404.5	537.3	-1867.2	-77.7

similar to the C-141A/B VSCF System study, this sensitivity analysis was performed in two separate steps:

1. Performing sensitivity analysis on the proposed power supply improvement while holding the LCC of the existing power supply at the baseline results.

2. Keeping the LCC total of the proposed power supply improvemənt at the baseline while performing sensitivity analysis of the existing power supply alternative. Table 15 and 16 highlight the results of these sensitivity analysis. Sensitivity analysis was also performed on other variables of interest. Table 17 shows the results of this analysis.

The RISKMC module was used to perform risk analysis on the total life cycle cost probabilities for the Improved Signal Processor Power Supply Alternative. Table 18 shows the parameters selected for unit cost, MTBF, and MTTR. The unit cost of the improved power supply alternative was varied from its proposed price to a value representing a 25 percent cost increase. The MTBF ranges chosen represented conservative estimates for the VSCF alternative. These estimates were used to assess LCC risks for cases where the VSCF MTBF would be significantly lower than the MTBF estimated by the VSCF Project Plan. Finally, the MTTR value was varied to capture up to a 300 percent increase in the depot maintenance hours required to repair the improved power supply. Since the probability distribution of this

Table 15

Sensitivity Analysis Examining LCC Effects of Changing Improved Power Supply MTBF, MTTR, and Unit Costs While Holding Current Power Supply LCC Constant (in thousands of dollars)

Variable	Percent of NEWPS Baseline*	Current Pwr Sup LCC**	Improved Pwr Sup LCC	Diff in both Dollars and Percentage
MTBF	25	$2404.4	$1515.3	$-889.1 (-37.0%)
MTBF	50	$2404.4	$1065.6	$-1338.8 (-55.7%)
MTBF	75	$2404.4	$912.4	$-1492.0 (-62.1%)
MTBF	100	$2404.4	$837.3	$-1567.1 (-65.2%)
MTBF	150	$2404.4	$759.2	$-1645.2 (-68.4%)
MTBF	300	$2404.4	$684.1	$-1720.3 (-71.5%)
MTBF	450	$2404.4	$656.1	$-1748.3 (-72.7%)
MTBF	550	$2404.4	$648.1	$-1756.3 (-73.0%)
MTTR	25	$2404.4	$782.7	$-1621.7 (-67.4%)
MTTR	50	$2404.4	$800.8	$-1603.6 (-66.7%)
MTTR	75	$2404.4	$819.1	$-1585.3 (-65.9%)
MTTR	100	$2404.4	$837.3	$-1567.1 (-65.2%)
MTTR	150	$2404.4	$873.8	$-1530.6 (-63.7%)
MTTR	300	$2404.4	$983.1	$-1421.3 (-59.1%)
MTTR	450	$2404.4	$1092.4	$-1312.0 (-54.6%)
MTTR	550	$2404.4	$1165.3	$-1239.1 (-51.5%)
UC	25	$2404.4	$808.1	$-1596.3 (-66.4%)
UC	50	$2404.4	$817.8	$-1586.6 (-66.0%)
UC	75	$2404.4	$827.6	$-1576.8 (-65.6%)
UC	100	$2404.4	$837.3	$-1567.1 (-65.2%)
UC	150	$2404.4	$856.8	$-1547.6 (-64.4%)
UC	300	$2404.4	$915.3	$-1489.1 (-61.9%)
UC	450	$2404.4	$973.8	$-1430.6 (-59.5%)
UC	550	$2404.4	$1012.8	$-1391.6 (-57.9%)

* Improved Power Supply MTBF Baseline = 10000 hrs
Improved Power Supply MTTR Baseline = 1.3 hrs
Improved Power Supply Unit Cost Baseline = $3000.00

Table 16

Sensitivity Analysis Examining LCC Effects of Changing Existing Power Supply MTBF, MTTR, and Unit Costs While Holding Improved Power Supply LCC Constant (in thousands of dollars)

Variable	Percent of EXISTPS Baseline*	Improved Pwr Sup LCC**	Existing Pwr Sup LCC	Diff in both Dollars and Percentage	
MTBF	25	$837.3	$10104.5	$9267.2	(1106.8%)
MTBF	50	$837.3	$4788.1	$3950.8	(471.8%)
MTBF	75	$837.3	$3203.1	$2365.8	(282.6%)
MTBF	100	$837.3	$2404.4	$1567.1	(187.2%)
MTBF	150	$837.3	$1609.9	$772.6	(92.3%)
MTBF	300	$837.3	$811.2	$-26.1	(-3.2%)
MTBF	450	$837.3	$543.6	$-293.7	(-35.1%)
MTBF	550	$837.3	$448.1	$-389.2	(-46.5%)
MTTR	25	$837.3	$1028.1	$190.8	(22.8%)
MTTR	50	$837.3	$1486.9	$649.6	(77.6%)
MTTR	75	$837.3	$1945.7	$1108.4	(132.4%)
MTTR	100	$837.3	$2404.4	$1567.1	(187.2%)
MTTR	150	$837.3	$3322.0	$2484.7	(296.8%)
MTTR	300	$837.3	$6074.6	$5237.3	(625.5%)
MTTR	450	$837.3	$8827.3	$7990.0	(954.3%)
MTTR	550	$837.3	$10662.4	$9824.9	(1173.4%)
UC	25	$837.3	$2295.2	$1457.9	(174.1%)
UC	50	$837.3	$2331.6	$1494.3	(178.5%)
UC	75	$837.3	$2368.0	$1530.7	(182.8%)
UC	100	$837.3	$2404.4	$1567.1	(187.2%)
UC	150	$837.3	$2477.2	$1639.9	(195.9%)
UC	300	$837.3	$2695.6	$1858.3	(221.9%)
UC	450	$837.3	$2914.0	$2076.7	(248.0%)
UC	550	$837.3	$3059.6	$2222.3	(265.4%)

* Existing Power Supply MTBF Baseline = 2950 hrs
Existing Power Supply MTTR Baseline = 11.1 hrs
Existing Power Supply Unit Cost Baseline = $4160.00

Table 17

Results of AN/ALR-46/69 Signal Processor Power Supply
Sensitivity Analysis for Selected Variables
Using CASA (in thousands of dollars)

Variable	Percent Change	Existing Pwr Supply LCC	Improved Pwr Supply LCC	Delta
Useful Life	25% decrease	$1839.8	$787.8	57.2%
System Op Hours	25% increase	$3002.6	$892.9	70.3%
NRTS rate	40% decrease	$2404.3	$837.3	65.2%
Inflation	5% per year	$3136.4	$932.9	70.3%
Inflation and Discount rate	5%Inf/10%Disc	$1903.6	$764.7	59.8%

Table 18

Parameters Selected for AN/ALR-46/69 Improved
Signal Processor Power Supply Risk Analysis

Variable	Distribution	Lowest Value	Highest Value
Unit Cost	Uniform	$3,000.00	$4500.00
MTBF	Uniform	6000 hrs	10000 hrs
MTTR	Uniform	1.5 hrs	4.5 hrs

proposed data was unknown, as with the C-141 VSCF analysis, the researcher chose to use the uniform distribution.

The maximum number of iterations (1000) was also chosen for the AN/ALR-46/69 Improved Power Supply Monte Carlo Simulation. The maximum number of iterations were used in an effort to add statistical significance to the use of the uniform distribution. Figure 6 shows the results of the risk analysis for the improved power supply alternative.

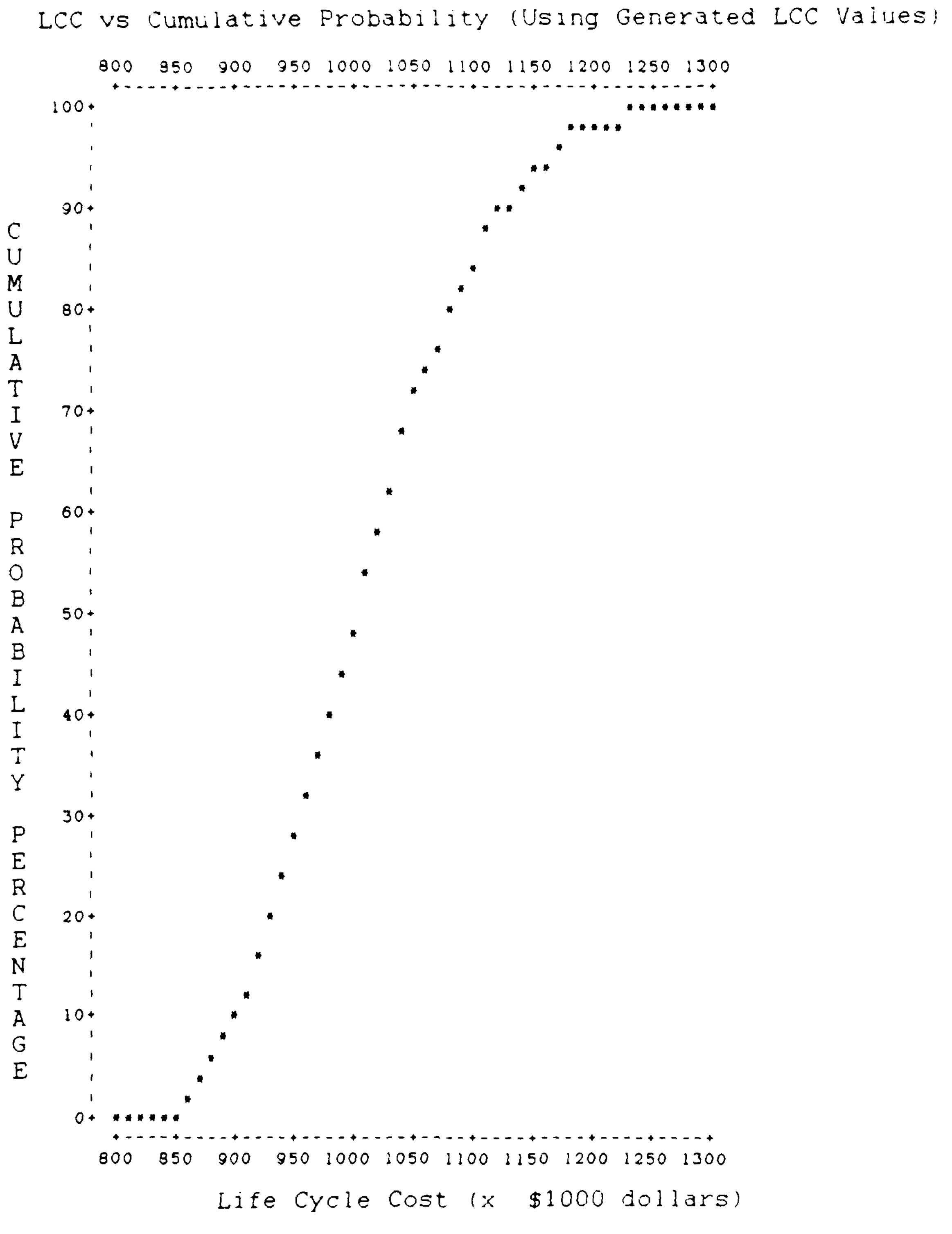

Figure 6. Cumulative LCC Probability Curve for AN/ALR-46/69 Improved Signal Processor Power Supply Alternative

Findings. The initial analysis showed that the total LCC difference between the two alternatives was about $1.56 million dollars, with the improved power supply alternative being the less costly alternative. Additionally, the operational and support cost savings of the proposed power supply improvement was about $2.06 million dollars. With the original $300 thousand dollar investment cost, this represented a ROI of about 6.87 to 1. However, with the increase in project investment costs of an additional $300 thousand dollars, the ROI decreased to about 3.43 to 1.

This original return on investment closely mirrored the 6.95 to 1 ROI estimated by the original PRAM Project Plan. This seems to strongly collaborate the original study performed by the PRAM staff. This was because the MTBF values used in the two studies were significantly different. The MTBF used in the original study was 1950 hours, versus 2960 hours used for the quantitative analysis using CASA. The value of 2960 hours was used because it more accurately estimated the MTBF of the Signal Processor Power Supply across the different using weapons systems (see page 76-79 for an explanation of the data aggregation process). Had the model used the 1950 MTBF value, the cost savings would have exceeded $3.2 million dollars, representing a ROI of over 10.6 to 1 if only $300 thousand dollars was used as an investment cost or about 5.4 to 1 using a $600 thousand dollar investment cost.

In addition to the baseline analysis, the extensive sensitivity analysis performed showed that the improved power supply alternative proved to be the more feasible cost alternative for a wide range of critical variable values (see Tables 15-17). As Table 16 highlights, the current power supply would be the more viable alternative only if the MTBF of the existing power supply had been underestimated by several thousand hours.

The limited risk analysis performed showed that total LCC for the improved power supply alternative could be expected to range between $850 thousand and about $1.225 million dollars. Using the 95 percent probability figure of $1.2 million dollars to represent a conservative LCC estimate, the operational and support cost savings would still amount to about $1.6 million dollars. This would still demonstrate a positive ROI of about 2.67 to 1, if the $600 thousand dollar figure was used as the baseline project development cost.

Limitations of CASA. While CASA proved to be quite flexible for performing the trade off analyses for both the C-141A/B VSCF System and the AN/ALR-46/69 Signal Processor Power Supply, it had some limitations which impacted the overall analysis. As with SILCC, CASA used formulas designed to calculate optimal spares provisioning for each alternative, rather than actual spares provisioning. This may have caused both studies to underestimate the acquisition costs of spares for each alternative in both the C-141A/B VSCF System analysis as well as the AN/ALR-46/69 Signal Processor Power Supply analysis. However, with the flexibility that CASA has to include both miscellaneous acquisition and C&S costs, these categories could be used to reflect a wide variety of spares provisioning policies. Even using these categories, there still is a high probability that CASA would inaccurately calculate spares provisioning.

The other challenge to using CASA was to determine the proper system monthly operating hours. In the C-141A/B VSCF analysis, the system operating hours of both the VSCF and the CSD mirrored the weapon system flying hours. However, with the MTBF calculations for the AN/ALR 46/69 Signal Processor Power Supply being calculated as a fraction of weapon system operating hours, the actual system hours to use for the monthly system operating hours input became somewhat muddled. The researcher decided to use weapon system operating hours for the baseline analysis, but also performed a comparison analysis using the fractional calculation as well. As could be expected, the fractional (.4) value resulted in a lower operational and support cost savings ($1.32 million dollars using the fractional value versus $2.06 million dollars using the full weapon system operating hours). However, even using this lower fractional value, the ROI was still about 2.2 to 1.

Two other CASA limitations, while not seriously hindering the analyses undertaken, nevertheless should be mentioned, since they did slow down the overall pace of the analysis. Although the actual CASA software was easy to use and provided a large amount of on line help, the CASA user's manual was difficult to use. The explanation of how different formulas were used in various CASA calculations was difficult to follow. Many hours were spent reviewing the user's manual and several program runs were needed by the researcher to learn how the various formulas were integrated into various CASA models. Additionally, as opposed to SILCC, CASA documentation did not provide any guidance about where to locate data needed for model use. While admittedly it is infeasible for a DOD developed model to even broach this issue, without any guidance provided about where to gather the data needed for model inputs, the use of the model to perform quantitative analysis becomes much more difficult.

SIDAC Analysis Assistance

During the initial phases of this study, the author used the Supportability Investment Decision Analysis Center (SIDAC) model catalog as a resource for assistance in determining which models to use for the study and where to locate data sources needed model inputs. Several people from Dynamics Research Corporation, who are members of the SIDAC concept exploration team, also offered some general assistance in locating data sources, determining model utility, and obtaining some model software.

The SIDAC model and data catalogs did provide the researcher with a starting point for performing analysis, with the data catalog providing the most assistance. The data catalog provided the researcher with functional descriptions of several existing Air Force data systems along with the office of primary responsibility and point of contact. The model catalog was more limited in its utility, however. While it did provide a general description of almost all models surveyed in this study, the only model that was described with enough detail to make a utilization decision was LAMP/LAWS and SCOPE-MOD (42:42-44,58-60). The documentation on all other models had to be obtained from the office of primary responsibility before the researcher was able to obtain enough information as to model use.

However, as the SIDAC was still undergoing concept exploration during the research period of this study, its concept exploration team members were not familiar enough with any models used in this analysis to provide the author with any assistance regarding their capabilities or limitations. Additionally, while the model catalog provided an important starting point for the model investigation phase of this research, it was only in draft form when used by the author.

V. Conclusions And Recommendations

Review

The purpose of this research was to determine how the use of existing microcomputer-based logistics support models could improve the evaluation and validation of supportability assessment for major PRAM proposals. It assumed that microcomputer-based logistical support modeling had matured enough within the Air Force supportability community to conduct valid research into this area. Additionally, the research sought to determine the validity of using a tailored approach; identifying the benefits and limitations of such an approach.

One of the necessary steps in conducting this research was examining the existing qualitative analysis process, then attempting to adapt or modify that process to a more quantitative approach that would allow logistics support models to be used. The research accomplished this task, but not without overcoming significant challenges that are described in subsequent sections of this chapter.

It is important to realize that the research explored only those areas of the PRAM decision making process that could be quantified. Before the reader assumes that the author is advocating the use of models to quantify the entire PRAM project decision process, it should be reemphasized that the research focused only on how microcomputer logistics support models could improve the cost/benefit analysis. Some of the key variables that must be considered in the complete analysis and decisions for any PRAM project were, and may always be, qualitative in nature. Key decision variables such as the technical risk of the project and the level of CPO/SPM/MAJCOM commitment are often subjective and may prove difficult, if not impossible, to quantify.

Research Results

The tailored methodology used in this research allowed the researcher to adequately perform the quantitative cost/benefit analysis for each of the PRAM projects used in this thesis. However, since each phase of the research provided the author with interesting and sometimes difficult challenges, perhaps the best way to discuss the research results is to highlight the results as they occurred, by examining the:

1. decision level analysis;
2. initial model survey and data collection;
3. final model selection;
4. model use in performing quantitative analysis;
5. SIDAC analysis assistance.

Decision Level Analysis. Performing decision level analysis proved to be the cornerstone to the successful application of the tailored methodology. Without knowing how the PRAM decision process worked, as well as the measures of merit that individual PRAM program managers and senior PRAM management were using to evaluate each project, it would not have been possible to select the proper supportability model.

As stated in chapters 3 and 4, determining the level of analysis required two steps:

1. determining the decision orientation(s);

2. evaluating the amount of data available.

This process was relatively uncomplicated. The in-depth evaluation of each PRAM Project Plan and unstructured interviews with each respective Project Manager, together with follow-on conversations with senior PRAM management, took the author about two weeks.

Although this procedure was uncomplicated, by determining the decision orientation(s) required and the data available for each project, it was possible to develop a matrix of analysis complexity to assist in the model selection. The use of this matrix greatly facilitated searching for and selecting an appropriate model.

Initial Model Survey and Data Collection. The process of finding microcomputer-based logistics support models that would match the level of analysis required for each PRAM project proved to be a challenging task. Since none of the managers of the PRAM projects studied had any experience with the use of microcomputer models, the researcher had to rely on several outside agencies for assistance in the model search process.

The initial model survey was conducted using the Defense Logistics Service Information Exchange (DLSIE) and SIDAC logistics support model catalogs. However, the only information both these model catalogs provided was brief summary information about supportability models and their Office of Primary Responsibility. Nevertheless, the model catalogs did provide an important starting point, because most of the model descriptions outlined the decision orientation of the model. Being able to obtain the decision orientation of the model helped to drastically reduce the number of candidate models.

The most important sources of information regarding potentially useful supportability models turned out to be the AFIT Center of Excellence for Reliability and Quality, as well as other AFIT professors familiar with supportability models. It was through the assistance of personnel associated with this agency that the author was finally able to narrow the candidate models down to a workable level.

None of the assistance provided, however, allowed the researcher to assess any capabilities of the models beyond the decision orientation of the model. In order to obtain an understanding of even the most basic capabilities of the candidate models, it was necessary to obtain the documentation from the office of primary responsibility for each of the candidate models. Only after a brief review of the model documentation was the researcher able to perform an initial capability assessment of each candidate model.

Data Collection. As previously stated, during the initial model survey, the researcher quickly determined the data existing on each of the PRAM projects would not prove adequate for candidate model use. At this point, a major additional data collection effort was required.

The development of a fairly standard data collection worksheet proved to be instrumental in allowing the research to continue. Very little additional data was needed after data was collected using the standard data elements listed on the worksheet.

The SIDAC data catalog proved to be an invaluable asset in tracking down sources of data available for each project. Though the use of the SIDAC data catalog, as well as additional assistance from knowledgeable SIDAC concept exploration personnel, the sources of most of the additional data were identified.

The quality and accuracy of both the original PRAM data and the additional data collected proved to be major issues throughout the course of the entire research. While these issues may admittedly affect the value of the quantitative analysis performed, it would be a greater disservice not to adequately discuss the problems that were identified in the process of conducting this research.

Data accuracy was especially troublesome for the F-15C/D Improved Aircraft Wheel analysis and the AN/ALR-46/69 Signal Processor Power Supply analysis. For the F-15C/D Improved Aircraft Wheel Project, the similar data elements gathered from MODAS, the D041 data system, and the Landing Gear Item Manager's office were often inconsistent. Unfortunately, these were the only sources for project logistics support data. The tentative solution was to use data that originated from the Landing Gear Item Manager's office. However, after several phone conversations with the equipment specialist in the IM's office, it was discovered that the IM's office was obtaining their data from the same data sources as the researcher, and was often unsure of the accuracy of the data themselves. Additionally, in performing the data collection for the AN/ALR-46/69, the researcher discovered that the data used in the original PRAM Project Plan was questionable because, although the Signal Processor Power Supply was used in more than 17 different weapon systems, the IM had only used the data from the F-15 and the B-52 weapon systems to perform their analysis. This incomplete analysis necessitated the development of the reliability data aggregation methodology in order to provide a more accurate source of data for project analysis. The entire data aggregation was a tedious and complex task, one which many other analysts may not even attempt.

or abandoned before the process of data aggregation was completed.

Another factor that had considerable bearing on data accuracy was the amount of previous data screening accomplished on each project by the original PRAM project manager. The primary reason that data accuracy problems were not as severe for the C-141A/B VSCF System as they were for the two other projects was due to the efforts taken by a member of the PRAM staff to ensure that the data used in the PRAM analysis for the C-141A/B VSCF System came from credible sources. Original PRAM data collection efforts were not quite as meticulous for the other two projects.

Final Model Selection. The data accuracy problems encountered lead the researcher to choose the sensitivity analysis capabilities of the various candidate models as the key factor in final model selection. It became extremely important that any models selected for use be capable of providing the researcher with the capability to perform sensitivity analyses on key decision variables.

The two models used for conducting the project analysis, SILCC and CASA, both provided these extensive sensitivity analysis capabilities. In addition to the strong sensitivity analysis capabilities exhibited by both models, each had unique capabilities that further compensated for data uncertainties. SILCC had a feature that rank-ordered the sensitivity of each variable used in the analysis. This feature provided the researcher with immediate visibility of the most critical variables, allowing the bulk of the analysis to be focused on those variables. CASA, while not providing the rank-ordering feature found in SILCC, allowed the researcher to accomplish risk analyses as well as sensitivity analyses. These features mitigated the effects of data uncertainty.

In addition to the strong sensitivity analysis capabilities demonstrated by both SILCC and CASA, these models [illegible] captured other features needed for providing the required analysis. They both provided good matches to the level of analysis required for the various projects. Additionally, they both had user-friendly features which greatly facilitated data entry and model use. They also provided capabilities to perform quick on-line variable comparisons between alternatives, a feature that significantly reduced analysis time.

Using Models to Perform Quantitative Analysis. The use of microcomputer models to perform quantitative supportability assessment did provide some important benefits not previously available to the PRAM staff. However, while these analysis tools provided added value to the cost-benefit analysis for each project, their use was not without some limitations that affected the overall quality of the analysis. This section will discuss the benefits of using the models first and then discuss their limitations.

Table 19

Comparison of ROI Calculations

Project	PRAM Project Plan ROI	Modeling ROI
F-15C/D Improved Aircraft Wheel[1]	12.6 to 1	3.8 to 1
C-141A/B VSCF System	.51 to 1	.38 to 1
AN/ALR-46/69 Signal Processor Power Supply	6.95 to 1	6.87 to 1

Benefits of Microcomputer-based Logistics Model Use. The use of these microcomputer-based logistics support models to perform cost/benefit analysis provided some important enhancements to the cost/benefit analysis for each project in this study. The use of these microcomputer models required the researcher to capture significantly greater amounts of data for each of the three projects than was available in the original PRAM documents. This resulted in more detailed assessments of the project costs than reported in the original PRAM Project Plans. Additionally, as shown by Table 19, the model results revealed that in at least two of the three projects, the lack of significant data caused the original PRAM staff analyst to overestimate the project's estimated return on investment. Although project costs were overestimated in two of the three projects analyzed, the modeling analysis collaborated the basic recommendations of the original PRAM Project Plan analysis. Quantitative analysis using the selected models resulted in overall positive ROIs for the two projects originally having positive ROIs in the PRAM project Plans. Additionally, the only project having an unfavorable ROI in the original PRAM Project Plan also resulted in a unfavorable ROI from the modeling analysis.

More important than the bottom line ROI, however, is the magnitude of the differences. While the use of modeling did not refute any of the original analyses, for those projects that originally might have marginally favorable or unfavorable ROIs, one might infer that use of modeling may result in different investment decisions than those resulting from the use of qualitative techniques alone. Since none of the projects had marginal ROIs (those close to a 1 to 1 ratio), more research would have to be done in this area before being able to make any definitive claims, however.

Several reasons can be suggested for the differences in the original PRAM Project Plan and the modeling ROI's. First, the original analysis focused on only a portion of the relevant data available to perform the proper trade off analyses. Many important data elements were either left out of these original analyses or, as in the case of the AN/ALR-46/69 Signal Processor Power Supply Analysis, were incomplete. Second, both models used in this study utilized optimal spares provisioning formulas in the quantitative analysis, whereas all three PRAM analyses used the actual known maintenance spares figures from the various depots. The actual depot spares for all three projects was significantly higher than the optimal spares calculated by the two models (by greater than 5 to 1 for all three projects). However, while this may be a problem for comparing alternative spares costs for components that have not been procured, in all three of the projects analyzed, all necessary spares had been procured for the existing alternatives. The use of spares provisioning costs in ROI calculations would have overinflated the ROI of the proposed improvements. Moreover, the use of spares cost in the cost/benefit calculations when they have become sunk costs for the existing alternatives would result in incorrect analysis. The use that both models made of optimal spares provisioning formulas significantly reduced the number of spares used in all LCC calculations, therefore reflecting a more thorough analysis.

Besides the more thorough analysis capabilities offered by the models, they offered the ability to perform rapid sensitivity analyses of several critical variables. As such, once the data had been entered and the baseline analysis performed, it was a relatively uncomplicated task to analyze the effects of changes in critical variable values on overall LCC costs and project ROIs. These sensitivity features allowed the researcher to determine at what values of unit cost. MTBF. MTTR. etc., the proposals became either favorable or unfavorable relative to the existing alternatives. Once the baseline analysis had been performed, most of the sensitivity analyses could be performed in less than 20 minutes. Without the use of microcomputer-based models to perform the sensitivity analyses, the time required to perform such comparisons would have substantially increased.

Another benefit of using one of the microcomputer models, was the ability to accomplish quantitative risk analysis. While the risk analysis performed in this research was quite limited in scope, any number of values and probability distributions could be used to quantitatively examine the economic risks of the projects analyzed with CASA. The capability to perform this type of risk analysis does not currently exist within PRAM.

Limitations of Microcomputer Model Use. While the models used added significant value in performing the cost benefit analysis, they were not without limitations. Since the specific limitations of each model have already been addressed, this section will describe the limitations and restrictions of model use as they generally apply to the PRAM program office and its staff.

Proper quantitative analysis could not have been performed without a thorough understanding of how both models functioned. This required the researcher to become familiar with not only data required for model use and the overall model structure, but in some cases, required an understanding of how various mathematical and statistical formulas were used in performing various calculations. While this was a very time intensive process, without a thorough understanding of the models, they may have been improperly used.

The amount of time needed to learn how a single model operates was very time intensive. Additionally, while the use of a tailored methodology proved essential for this project, it also meant that the researcher was required to become familiar with the documentation and operation of several models. While this proved feasible in a research environment, the use of a tailored modeling methodology may prove to be impractical without use of full time analysts. The primary goal of PRAM program managers is to provide overall management of their assigned programs and projects. The performance of economic cost/benefit analysis of the project is only one of the many competing tasks they are required to perform in the project management process. Additionally, at any given time, a single PRAM Program Manager may be responsible for the management of as many as 15 to 20 projects (2). Given these parameters, the amount of time a PRAM program manager would have to devote to learning how to use even a single model may be quite limited. However, this limitation reinforces the need for a full time analysis capability such as the Supportability Investment Decision Analysis Center.

SIDAC Analysis Assistance. While the analysis assistance given to the researcher by the SIDAC concept exploration team was peripheral, it nevertheless proved to be important. It provided general guidance concerning data sources and supportability models at several key phases of the entire research. Without using the draft copies of the SIDAC data and model catalogs, the research would have taken much longer to complete. The SIDAC concept exploration was being conducted by the Dynamics Research Corporation (DRC), and the assistance provided by many of their personnel in providing general direction for this research proved to be very valuable. However this researcher was unable to obtain much assistance from the DRC personnel in evaluating models that they did not own. Capability assessment of non DRC models had to be performed exclusively by the author.

Recommendations for Further Research

Though faced with some challenging obstacles during some of the phases of this research, this study demonstrated the value of using microcomputer-based logistics support models to perform quantitative analysis for the PRAM Program Office. Additionally, it supported the tailored approach to performing such analysis. Indeed, if the researcher had attempted to accomplish this research using only one model, meaningful results would have been difficult, if not impossible, to obtain.

As with most other research, however, the process of obtaining the data, performing model survey and selection, and using the models to perform different levels of supportability analysis highlights areas in which improvements are needed and follow up research should be performed. Based on the analysis and findings of this thesis, the following recommendations should be considered:

1. While AFLC is currently taking several steps to modernize their reliability and maintainability data collection systems through the Requirements Data Base project, R&M data accuracy and quality were problematic for this research. Possible reasons suggested for R&M data accuracy problems have been a lack of data systems input editing integrity, combined with lack of attention to data entry by field technicians. Although some work has been done in this area to correct possible causes of data accuracy problems, data accuracy issues encountered during this project suggest that more work needs to be accomplished, especially with efforts that focus on solutions to data accuracy problems. Any research in this area should also include an analysis of the difficulties other supportability analysts have had in obtaining quality data and how it has affected their overall analyses.

2. The PRAM Program Office should investigate the possibility of developing a standard project data collection worksheet, such as that which appears in Appendix A, for the

cost/benefit analysis of major PRAM projects. The use of such project worksheets could improve the thoroughness of major PRAM project analyses. Any worksheet developed should allow for flexibility in data collection, however, since data requirements may vary between projects. Nevertheless, these project data collection worksheets, if properly implemented, would provide the PRAM staff with more supportability data than is currently being received for many PRAM proposals.

3. The PRAM Program Office should perform an assessment of how to practically incorporate the use of a tailored modeling approach to the quantitative cost/benefit analysis portions of major PRAM projects. This research demonstrates only the feasibility of using a tailored modeling approach to perform project quantitative cost/benefit analysis. Although it discussed some of the problems of implementing this approach, it was not designed to address the management challenges that may be encountered in trying to implement such an approach. It would be very appropriate, however, for senior PRAM management personnel to address the implementation issues. Specifically, if senior PRAM managers decide to use microcomputer based logistics models to perform further supportability analysis, they should decide how to best implement their use. Implementation strategies to be considered should include:

a. the familiarization and training of PRAM program managers in the use of logistics support model use;

b. the development of an in-house supportability analysis section that would provide the capability to perform a wide variety of project analysis;

c. the use of other Air Force or contractor sources such as the SIDAC to perform these analyses;

d. some combination of these three approaches.

4. Follow up research should be conducted into the feasibility of applying the tailored modeling methodology for other logistics support agencies. This research only demonstrated the feasibility of using this tailored approach in the PRAM cost/benefit analysis process. It could be safely assumed that other agencies within the supportability community, such as system program managers and item managers at the different ALC's, use different decision procedures. Nevertheless, further research may demonstrate the value of applying this same process to other areas of the supportability decision making process.

Additionally, based on the findings of this research, this author believes that the AF and the DOD should continue the efforts to fully implement the SIDAC. While the author could not take advantage of all of the proposed SIDAC capabilities because of their limited availability during the SIDAC concept exploration phase, the benefits of a central repository for supportability assessment information were clearly demonstrated. Additionally, at different phases of this entire research, when difficult obstacles presented themselves, both government and contractor personnel involved with the SIDAC concept exploration effort offered several suggestions which helped keep the research moving forward. This type of assistance, if permanently incorporated into a fully developed SIDAC and made widely available to the supportability community, could facilitate the supportability assessment process of the Air Force, as well as the entire Department of Defense. Moreover, while the draft copies of the model catalog did not provide the author with the ability to fully assess the capability of the many supportability models available for use, this catalog has been greatly improved since this research was initiated. If properly implemented, a model catalog that would detail not only the capabilities of the models, but detail the data sources as well, would provide an invaluable tool to the entire logistics community in its quest to add value to the supportability analysis process.

Appendix A: Sample Project Worksheet

PROJECT WORKSHEET	DATA AVAILABLE FOR ANALYSIS				Pg ___ of ___	
PROJECT:	ALTERNATIVE A:			ALTERNATIVE B:		
	DATA ELEMENT:	UNIT AMT	SOURCE:	DATA ELEMENT:	UNIT AMT	SOURCE:
PROJECT DESCRIPTION:	Federal Stock Number:			Federal Stock Number:		
	Part Number:			Part Number:		
	Work Unit Code:			Work Unit Code:		
	Unit Price:			Unit Price:		
	Estimated Useful Life:			Estimated Useful Life:		
DECISION ORIENTATION: __ Combat Capability __ Vulnerability/Survivability __ Reliability __ Maintainability __ Mobility __ Manpower __ Life Cycle Costs	Mean Time btw Failure(MTBF)			Mean Time btw Failure(MTBF)		
	Mean Time btw Demand(MTBD)			Mean Time btw Demand(MTBD)		
	Mean Time btw Removal(MTBR)			Mean Time btw Removal(MTBR)		
	Mean Time to Repair (Base)			Mean Time to Repair (Base)		
	Mean Time to Repair(Depot)			Mean Time to Repair (Depot)		
	Number of Aircraft:			Number of Aircraft:		
NOTES:	Number of Bases:			Number of Bases:		
	Number of Component Spares			Number of Component Spares		
	Weight:			Weight :		
	Size:			Size:		
	Annual Operating Hours per Aircraft: (average)			Annual Operating Hours per Aircraft: (average)		

PROJECT WORKSHEET	DATA AVAILABLE FOR ANALYSIS				Pg ___ of ___	
PROJECT:	ALTERNATIVE A:			ALTERNATIVE B:		
	DATA ELEMENT:	UNIT AMT	SOURCE:	DATA ELEMENT:	UNIT AMT	SOURCE:
PROJECT DESCRIPTION:	Total Annual Operating Hrs			Total Annual Operating Hrs		
	Avg Monthly Operating Hrs			Avg Monthly Operating Hrs		
	Peak Monthly Operating Hrs			Peak Monthly Operating Hrs		
	Bench Check Service Rate			Bench Check Service Rate		
Primary System:	NRTS Rate			NRTS Rate		
DECISION ORIENTATION: __ Combat Capability __ Vulnerability/Surviv-ability __ Reliability __ Maintainability __ Mobility __ Manpower __ Life Cycle Costs	RTS Rate			RTS Rate		
	Base Condemn Rate			Base Condemn Rate		
	Depot Condemn Rate			Depot Condemn Rate		
	Base Repair Cycle Time			Base Repair Cycle Time		
	Depot Repair Cycle Time			Depot Repair Cycle Time		
	Base Manhours To Repair			Base Manhours To Repair		
NOTES: 1. Operating hours refer to system hours	Base Material Costs			Base Material Cost		
	Number Annual Base Repairs			Number Annual Base Repairs		
	Depot Manhrs To Repair			Depot Manhrs To Repair		
	Depot Material Costs			Depot Material Costs		
	Number Annual Depot Repairs			Number Annual Depot Repairs		

PROJECT WORKSHEET

PROJECT:

PROJECT DESCRIPTION:

DECISION ORIENTATION:

NOTES:

DATA AVAILABLE FOR ANALYSIS

ALTERNATIVE A:			ALTERNATIVE B:		
DATA ELEMENT:	UNIT AMT	SOURCE:	DATA ELEMENT:	UNIT AMT	SOURCE:

Appendix B: F-15C/D Improved MLG Wheel Project Worksheet

PROJECT WORKSHEET

PROJECT: Improved Main Landing Gear Wheels for F-15C/D aircraft

PROJECT DESCRIPTION: Unsolicited Proposal from Allied Signal Corporation to demonstrate the advantages of a new alloy main landing gear wheel

DECISION ORIENTATION:

- __ Combat Capability
- __ Vulnerability/Survivability
- __ Reliability
- __ Maintainability
- __ Mobility
- __ Manpower
- x Life Cycle Costs

NOTES:

1. Estimated Useful Life refers to component life.
2. For the F-15C/D aircraft, the Estimated Useful Life for this study was 20 years.
3. Where no data is entered under Alternative B, it is initially assumed to be the same as Alternative A.

Ogden ALC point of contact: Sam Najatifer AV458-6441

DATA AVAILABLE FOR ANALYSIS Pg 1 of 3

ALTERNATIVE A: 2014 Aluminum Alloy			ALTERNATIVE B: RST Alloy		
DATA ELEMENT:	**UNIT AMT**	**SOURCE:**	**DATA ELEMENT:**	**UNIT AMT**	**SOURCE:**
Federal Stock Number	1630010585912	OO-ALC/MMILBE	Federal Stock Number		
Part Number	2605691-1	OO-ALC/MMILBE	Part Number		
Work Unit Code	13AKB	MODAS	Work Unit Code		
Unit Price	$6780	OO-ALC/MMILBE	Unit Price	$7800	Allied proposal
Estimated Useful Life	10 years	OO-ALC/MMILBE	Estimated Useful Life	18 yrs	Allied proposal
Mean Time btw Failure(MTBF)			Mean Time btw Failure(MTBF)		
Mean Time btw Demand(MTBD)	2035.8hrs	OO-ALC/MMILBE	Mean Time btw Demand(MTBD)	4071.6hrs	Allied proposal
Mean Time btw Removal(MTBR)	668hrs	OO-ALC/MMILBE	Mean Time btw Removal(MTBR)	1002hrs	Allied proposal
Base Mean Time to Repair	8.42hrs	MODAS	Base Mean Time to Repair		
Depot Mean Time to Repair	12hrs	D041	Depot Mean Time to Repair		
Number of Aircraft	443	AFLC/LOC/SCO	Number of Aircraft		
Number of Bases	11	G033B	Number of Bases		
Number of Spares	1,080	OO-ALC/MMILBE	Number of Spares	222	Allied proposal
Weight	160.61bs	OO-ALC/MMILBE	Weight		
Size	5.27cu.ft.	OO-ALC/MMILBE	Size		
Annual Ops Hrs per Acft	261hrs	MODAS	Annual Ops Hrs per Acft		

PROJECT WORKSHEET	DATA AVAILABLE FOR ANALYSIS Pg 2 of 3					
PROJECT: Improved Main Landing Gear Wheels for F-15C/D	**ALTERNATIVE A:** 2014 Aluminum Alloy			**ALTERNATIVE B:** RST Alloy		
	DATA ELEMENT:	**UNIT AMT**	**SOURCE:**	**DATA ELEMENT:**	**UNIT AMT**	**SOURCE:**
PROJECT DESCRIPTION: See page 1	Total Annual Operating Hrs	115,644hrs	MODAS	Total Annual Operating Hrs		
	Avg Monthly Operating Hrs	9,637hrs	MODAS	Avg Monthly Operating Hrs		
	Peak Monthly Operating Hrs	13,467hrs	MODAS	Peak Monthly Operating Hrs		
	Bench Check Service Rate	N/A		Bench Check Service Rate		
Primary System: F-15C/D	NRTS Rate	.09	D041	NRTS Rate		
DECISION ORIENTATION:	RTS Rate	.91	D041	RTS Rate		
__ Combat Capability	Base Condemn Rate	N/A		Base Condemn Rate		
__ Vulnerability/Survivability	Depot Condemn Rate	.01	D041	Depot Condemn Rate		
__ Reliability	Base Repair Cycle Time	4 days	D041	Base Repair Cycle Time		
__ Maintainability	Depot Repair Cycle Time	54 days	D041	Depot Repair Cycle Time		
__ Mobility	Base Manhours To Repair	8.42hrs	MODAS	Base Manhours To Repair		
__ Manpower	Base Material Costs			Base Material Cost		
_x_ Life Cycle Costs	Number Annual Base Repairs	162	OO-ALC/MMILBE	Number Annual Base Repairs		
NOTES: 1. Operating hours refer to system hours	Depot Manhrs To Repair	12hrs	D041	Depot Manhrs To Repair		
	Depot Material Costs			Depot Material Costs		
	Number Annual Depot Repairs	533	OO-ALC/MMILBE	Number Annual Depot Repairs		

PROJECT WORKSHEET

PROJECT: Improved Main Landing Gear Wheels for F-15C/D

PROJECT DESCRIPTION:
See pg 1.

Primary System: F-15C/D

DECISION ORIENTATION:
- ___ Combat Capability
- ___ Vulnerability/Survivability
- ___ Reliability
- ___ Maintainabilty
- ___ Mobility
- ___ Manpower
- _x_ Life Cycle Costs

NOTES:

DATA AVAILABLE FOR ANALYSIS

ALTERNATIVE A: 2014 Aluminum Alloy			ALTERNATIVE B: RST Alloy		
DATA ELEMENT:	**UNIT AMT**	**SOURCE:**	**DATA ELEMENT:**	**UNIT AMT**	**SOURCE:**
Overhaul Cost per Wheel	$1633	OO-ALC/MMILBE	Overhaul Cost per Wheel	$1000	Allied proposal
Overhaul Cycle	2 years	OO-ALC/MMILBE	Overhaul Cycle	4 years	Allied proposal
Overhaul Cost per year	$ 816.5	OO-ALC/MMILBE	Overhaul Cost per year	$ 250	Allied proposal
Piece Parts	49	OO-ALC/MMILBE	Piece Parts		
PRAM Project Cost	0	PRAM Project Plan	PRAM Project Cost	$846,500	Allied proposal

Appendix C: C-141 VSCF System Project Worksheet

PROJECT WORKSHEET

PROJECT: C-141 Variable Speed Constant Frequency Electrical Generating System

PROJECT DESCRIPTION:
Proposed replacement system for the current C-141 Constant Speed Drive electical generating system.

Primary System: C-141A/B

DECISION ORIENTATION:
- __ Combat Capability
- __ Vulnerability/Survivability
- _x_ Reliability
- __ Maintainability
- __ Mobility
- __ Manpower
- _x_ Life Cycle Costs

NOTES:
1. Estimated Useful Life is for the C-141A/B aircraft.

DATA AVAILABLE FOR ANALYSIS Pg 1 of 3

ALTERNATIVE A: Constant Speed Drive			**ALTERNATIVE B**: Var Spd Cnst Freq Sys		
DATA ELEMENT:	**UNIT AMT**	**SOURCE**:	**DATA ELEMENT**:	**UNIT AMT**	**SOURCE**:
Federal Stock Number	1650007573862- 1650009303160-	(GE) PRAM Pro- (SUN) ject Plan	Federal Stock Number		
Part Number	3B9000-133(GE) 698471C(SUN)	PRAM Project Plan	Part Number		
Work Unit Code	23SQA(GE) 23SQP(SUN)	MODAS	Work Unit Code		
Unit Price	$60,133.76	PRAM Project Plan	Unit Price	$74,500	PRAM Project Plan
Estimated Useful Life	25 years	AFLCP 173-13	Estimated Useful Life		
Mean Time btw Failure(MTBF)	1595hrs	PRAM Project Plan	Mean Time btw Failure(MTBF)	4000hrs	PRAM Project Plan
Mean Time btw Demand(MTBD)	1704hrs	D041	Mean Time btw Demand		
Mean Time btw Removal(MTBR)		RAMDAS	Mean Time btw Removal(MTBR)		
Base Mean Time to Repair	16hrs	RAMDAS	Base Mean Time to Repair		
Depot Mean Time to Repair	48hrs	D041	Depot Mean Time to Repair		
Number of Aircraft	271	PRAM Project Plan	Number of Aircraft		
Number of Bases	10	PRAM Project Plan	Number of Bases		
Number of Spares	662	PRAM Project Plan	Number of Spares		
Weight	75lbs		Weight		
Size	.7 cu ft		Size		
Annual Ops Hrs per Acft	1026	MODAS	Annual Ops Hrs per Acft		

PROJECT WORKSHEET	DATA AVAILABLE FOR ANALYSIS					Pg 2 of 3
PROJECT: C-141 Variable Speed Constant Frequency Electrical Generating System	**ALTERNATIVE A**: Constant Speed Drive			**ALTERNATIVE B**: Var Spd Cnst Freq Sys		
	DATA ELEMENT:	**UNIT AMT**	**SOURCE**:	**DATA ELEMENT**:	**UNIT AMT**	**SOURCE**:
PROJECT DESCRIPTION: See page 1.	Total Annual Operating Hrs	278148.5hrs	MODAS	Total Annual Operating Hrs		
	Avg Monthly Operating Hrs	23179hrs	MODAS	Avg Monthly Operating Hrs		
	Peak Monthly Operating Hrs	26625hrs	MODAS	Peak Monthly Operating Hrs		
	Bench Check Service Rate	.0005	MODAS	Bench Check Service Rate		
Primary System:	NRTS Rate	.79	D041	NRTS Rate		
DECISION ORIENTATION: __ Combat Capability __ Vulnerability/Survivability x Reliability __ Maintainability __ Mobility __ Manpower x Life Cycle Costs	RTS Rate	.21	D041	RTS Rate		
	Base Condemn Rate	0	D041	Base Condemn Rate		
	Depot Condemn Rate	0	D041	Depot Condemn Rate		
	Base Repair Cycle Time	7 days	D041	Base Repair Cycle Time		
	Depot Repair Cycle Time	34 days	D041	Depot Repair Cycle Time		
NOTES: 1. Operating hours refer to system hours 2. GE part used in 75% of fleet - SUN used in 25% of fleet	Base Manhours To Repair	16hrs	RAMDAS	Base Manhours To Repair		
	Base Material Costs	6.30p/hr	AFLCP 173-13	Base Material Cost		
	Number Annual Base Repairs	109	D041	Number Annual Base Repairs		
	Depot Manhrs To Repair	48hrs	D041	Depot Manhrs To Repair		
	Depot Material Costs	14.52p/hr	AFLCP 173-13	Depot Material Costs		
	Number Annual Depot Repairs	612	D041	Number Annual Depot Repairs	100	PRAM Project Plan

PROJECT WORKSHEET

DATA AVAILABLE FOR ANALYSIS Pg 3 of 3

PROJECT: C-141 Variable Speed Constant Frequency Electical Generating System

PROJECT DESCRIPTION:
See page 1.

Primary System: C-141A/B

DECISION ORIENTATION:
- __ Combat Capability
- __ Vulnerability/Survivability
- x Reliability
- __ Maintainability
- __ Mobility
- __ Manpower
- x Life Cycle Costs

NOTES:
1. ** Annual Cost
2. *** Total Airframe Recurring Cost over C-141 useful life.

ALTERNATIVE A: Constant Speed Drive			ALTERNATIVE B: Var Spd Cnst Freq Sys		
DATA ELEMENT:	**UNIT AMT**	**SOURCE:**	**DATA ELEMENT:**	**UNIT AMT**	**SOURCE:**
Total Depot Repair Cost**	$2,265,624	PRAM Project Plan	Total Depot Repair Cost	$300,000	PRAM Project Plan
Unit Repair Cost	$3,702	PRAM Project Plan	Unit Repair	$3,000	PRAM Project Plan
Generator Repair Costs	$489,00p/yr	PRAM Project Plan	Generator Repair Costs	0	PRAM Project Plan
PRAM Project Cost	0	PRAM Project Plan	PRAM Project Cost	$4,000,000	PRAM Project Plan
Airframe Nonrecurring Cst	0	PRAM Project Plan	Airframe Nonrecurring Cst	$1,600,000	PRAM Project Plan
Airframe Recurring Cst***	0	PRAM Project Plan	Airframe Recurring Cst	$16,260,000	PRAM Project Plan

Appendix D: AN/ALR-46/69 Signal Processor Power Supply Project Worksheet

PROJECT WORKSHEET

PROJECT: AN/ALR46/69 Power Supply Improvement Program

PROJECT DESCRIPTION: Proposal to improve che reliability and maintainability of the the AN/ALR 46 and AN/ALR69 Power Supplies. This is a form, fit and function replacement affecting several different aircraft systems

DECISION ORIENTATION:
- __ Combat Capability
- __ Vulnerability/Survivability
- x Reliability
- x Maintainability
- __ Mobility
- __ Manpower
- x Life Cycle Costs

NOTES:
1. ** 94 CONUS bases, 40 Overseas bases

DATA AVAILABLE FOR ANALYSIS Pg 1 of 3

ALTERNATIVE A: Existing Pwr Supply			ALTERNATIVE B: Improved Pwr Supply		
DATA ELEMENT:	**UNIT AMT**	**SOURCE:**	**DATA ELEMENT:**	**UNIT AMT**	**SOURCE:**
Federal Stock Number	5865010103254EW 5865003572995EW	(PR) PRAM Project Mgr (ALT)	Federal Stock Number		
Part Number	308915-1(PR) 304296-2(ALT)	PRAM Project Manager	Part Number		
Work Unit Code	Varies	MODAS	Work Unit Code		
Unit Price	$4160	PRAM Project Plan	Unit Price	$3000	PRAM Project Plan
Estimated Useful Life	10 yrs	PRAM Project Plan	Estimated Useful Life		
Mean Time btwn Failure(MTBF)	2960hrs	Derived from MODAS	Mean Time btw Failure(MTBF)	10,000hrs	PRAM Project Plan
Mean Time btwn Demand(MTBD)	5712.1hrs	D041	Mean Time btwn Demand(MTBD)		
Mean Time btwn Removal(MTBR)	3263.4hrs	Derived from MODAS	Mean Time btwn Removal(MTBR)		
Base Mean Time to Repair	6.65hr	Derived from MODAS	Base Mean Time to Repair		
Depot Mean Time to Repair	11.18hrs	Derived from D041	Depot Mean Time to Repair	1.5hrs	PRAM Project Plan
Number of Aircraft	3319	AFLC/LOC/SCOs	Number of Aircraft		
Number of Bases **	134	AFLC/LOC/TLPW	Number of Bases		
Number of Spares	446	PRAM Project Plan	Number of Spares	87	PRAM Project Plan
Weight			Weight		
Size			Size		
Annual Ops Hrs per Acft	361.44	Derived from MODAS	Annual Ops Hrs per Acft		

PROJECT WORKSHEET

PROJECT: AN/ALR46/69 Power Supply Improvement Program

PROJECT DESCRIPTION:

See Page 1.

Primary System: Various Systems

DECISION ORIENTATION:
- ___ Combat Capability
- ___ Vulnerability/Survivability
- _x_ Reliability
- _x_ Maintainability
- ___ Mobility
- ___ Manpower
- _x_ Life Cycle Costs

NOTES:
1. Operating hours refer to system hours
2. Data derived from D041 and MODAS using weighted average method

DATA AVAILABLE FOR ANALYSIS

Pg 2 of 3

ALTERNATIVE A: Existing Pwr Supply			ALTERNATIVE B: Improved Pwr Supply		
DATA ELEMENT:	**UNIT AMT**	**SOURCE:**	**DATA ELEMENT:**	**UNIT AMT**	**SOURCE:**
Total Annual Operating Hrs	1,048,957	MODAS	Total Annual Operating Hrs		
Avg Monthly Operating Hrs	87,413	MODAS	Avg Monthly Operating Hrs		
Peak Monthly Operating Hrs	115,218	MODAS	Peak Monthly Operating Hrs		
Bench Check Service Rate	0	MODAS	Bench Check Service Rate		
NRTS Rate	.895	Derived from D041	NRTS Rate		
RTS Rate	.105	Derived from D041	RTS Rate		
Base Condemn Rate	0	D041	Base Condemn Rate		
Depot Condemn Rate	.033	Derived from D041	Depot Condemn Rate		
Base Repair Cycle Time	5 days	D041	Base Repair Cycle Time		
Depot Repair Cycle Time	27 days	Derived from D041	Depot Repair Cycle Time		
Base Manhours To Repair	6.65hrs	Derived from MODAS	Base Manhours To Repair		
Base Material Costs	$43.28	PRAM Project Plan	Base Material Cost		
Number Annual Base Repairs	211	D041	Number Annual Base Repairs		
Depot Manhrs To Repair	11.18hrs	Derived from D041	Depot Manhrs To Repair	1.5hrs	PRAM Project Plan
Depot Material Costs	$78	PRAM Project Plan	Depot Material Costs	$10	PRAM Project Plan
Number Annual Depot Repairs	273	D041	Number Annual Depot Repairs		

PROJECT WORKSHEET

PROJECT: AN/ALR46/69 Power Supply Improvement Program

PROJECT DESCRIPTION:
See page 1.

DECISION ORIENTATION:
__ Combat Capability
__ Vulnerability/Survivavility
_x Reliability
_x Maintainability
__ Mobility
__ Manpower
_x Life Cycle Costs

NOTES:
1. * Includes direct labor, material, and overhead costs

DATA AVAILABLE FOR ANALYSIS Pg 3 of ?

ALTERNATIVE A: Existing Pwr Supply			**ALTERNATIVE B:** Improved Pwr Supply		
DATA ELEMENT:	**UNIT AMT**	**SOURCE:**	**DATA ELEMENT:**	**UNIT AMT**	**SOURCE:**
Unit Repair Cost(Depot)	$587	PRAM Project Plan	Unit Repair Cost(Depot)	$70	PRAM Project Plan
Depot Manhr Repair Cost*	$46.32	PRAM Project Plan	Depot Manhr Repair Cst	$46.32	PRAM Project Plan

Appendix E: Initial Input Values for F-15C/D 2014 Alternative

17:32:39 07-15-89

Life Cycle Cost Input Parameter Variables

File Name: 2014alum

Work Unit Code Name: WHEEL,MLG
Work Unit Code: 13AKB
Manufacturer: BENDIX
National Stock Number: 1630010585612
Data gathered by: CAPT DAVID MARTIN
File Time and Date: 11:33:13 06-23-89

DEVC	Development Cost	$	0.
SYSI	System Investment Cost	$	0.
SEC	Support Equipment Cost	$	0.
M	Number of Operating Bases	-	11.
AOH	Average Annual Operating Hours	Hr	115644.0
POH	Peak Month Operating Hours	Hr	13467.0
PIUP	Projected Inventory Usage Period	Yr	20.
UC	Unit Cost of Item As a Spare	$	6780.00
W	Weight of Item	Lb	160.60
MTBD	Mean Time Between Demand	Hr	2035.8
MTBR	Mean Time Between Removal	Hr	668.0
NRTS	Fraction of Removals Not Reparable at Base	-	.090
RTS	Fraction of Removals Reparable at Base	-	.910
COND	Fraction of Removals Condemned	-	.010
PAMH	Preparation and Access Manhours	Hr	.50
RMH	Replacement Manhours	Hr	8.40
SMI	Scheduled Maintenance Interval	Hr	.00
SMH	Scheduled Maintenance Manhours	Hr	.00
BCMH	Bench Check Manhours	Hr	.00
BMH	Base Maintenance Manhours	Hr	8.42
BMC	Base Direct Material Cost/Failure	$	6.30
BRCT	Base Repair Cycle Time	Mo	4.000
DMH	Depot Maintenance Manhours	Hr	12.00
DMC	Depot Direct Material Cost/Failure	$	1375.48
PA	Number of Reparable Items	-	1.
PP	Number of Consumable Items	-	49.
PCB	Number of Consumable Items Stocked at Base	-	0.
OST	Order and Shipping Time	Mo	.700
DRCT	Depot Repair Cycle Time	Mo	1.800
BLR	Base Labor Rate/Manhour	$	9.57
DLR	Depot Labor Rate/Manhour	$	21.46
PSC	Packing and Shipping Cost/Pound	$	3.00
SA	Base Inventory Management Cost/Item/Year	$	2.55
IMC	Initial Inventory Management Cost/Item	$	.00
RMC	Recurring Inventory Management Cost/Item/year	$	230.50

Appendix F: Initial Input Values for F-15C/D RST Alternative

17:36:12 07-15-89

Life Cycle Cost Input Parameter Variables

File Name: newrst

Work Unit Code Name: WHEEL,MLG
Work Unit Code: NONE
Manufacturer: BENDIX PROPOSAL
National Stock Number: NONE AVAILABLE
Data gathered by: CAPT DAVID MARTIN
File Time and Date: 15:49:15 06-30-89

DEVC	Development Cost	$	0.
SYSI	System Investment Cost	$	846500.
SEC	Support Equipment Cost	$	0.
M	Number of Operating Bases	-	11.
AOH	Average Annual Operating Hours	Hr	115644.0
POH	Peak Month Operating Hours	Hr	13467.0
PIUP	Projected Inventory Usage Period	Yr	20.
UC	Unit Cost of Item As a Spare	$	7800.00
W	Weight of Item	Lb	160.60
MTBD	Mean Time Between Demand	Hr	4071.0
MTBR	Mean Time Between Removal	Hr	1002.0
NRTS	Fraction of Removals Not Reparable at Base	-	.090
RTS	Fraction of Removals Reparable at Base	-	.910
COND	Fraction of Removals Condemned	-	.010
PAMH	Preparation and Access Manhours	Hr	.50
RMH	Replacement Manhours	Hr	8.40
SMI	Scheduled Maintenance Interval	Hr	.00
SMH	Scheduled Maintenance Manhours	Hr	.00
BCMH	Bench Check Manhours	Hr	.00
BMH	Base Maintenance Manhours	Hr	8.42
BMC	Base Direct Material Cost/Failure	$	6.30
BRCT	Base Repair Cycle Time	Mo	4.000
DMH	Depot Maintenance Manhours	Hr	12.00
DMC	Depot Direct Material Cost/Failure	$	743.00
PA	Number of Reparable Items	-	1.
PP	Number of Consumable Items	-	49.
PCB	Number of Consumable Items Stocked at Base	-	0.
OST	Order and Shipping Time	Mo	.700
DRCT	Depot Repair Cycle Time	Mo	1.800
BLR	Base Labor Rate/Manhour	$	9.57
DLR	Depot Labor Rate/Manhour	$	21.46
PSC	Packing and Shipping Cost/Pound	$	3.00
SA	Base Inventory Management Cost/Item/Year	$	2.55
IMC	Initial Inventory Management Cost/Item	$	.00
RMC	Recurring Inventory Management Cost/Item/year	$	230.50

Appendix G: Ranked Sensitivity Analysis of 2014 Variables

17:53:28 07-15-89

Life Cycle Cost Sensitivity Analysis

File Name: 2014alum

Work Unit Code Name: WHEEL,MLG
Work Unit Code: 13AKB
Manufacturer: BENDIX
National Stock Number: 1630010585612
Data gathered by: CAPT DAVID MARTIN
File Time and Date: 11:33:13 06-23-89

Variables Changed by Delta = .05
Confidence Level of Base and Depot Spares = .95

Rank	Variable	Original Value	Upper	Lower	Sensitivity
1	PIUP	20.00	21.00	19.00	142.286900
2	MTBR	668.00	701.40	634.60	139.014400
3	AOH	115644.00	121426.20	109861.80	138.677100
4	NRTS	.70	.74	.66	129.683400
5	PSC	3.00	3.15	2.85	68.165950
6	W	160.60	168.63	152.57	68.165640
7	DMC	1375.48	1444.25	1306.71	50.943720
8	DLR	21.46	22.53	20.39	9.537850
9	DMH	12.00	12.60	11.40	9.537850
10	UC	6780.00	7119.00	6441.00	8.392208
11	BLR	9.57	10.05	9.09	5.785517
12	RMH	8.40	8.82	7.98	4.253409
13	COND	.01	.01	.01	4.144300
14	RMC	230.50	242.02	218.98	3.592797
15	PP	49.00	51.45	46.55	3.451903
16	M	11.00	11.55	10.45	3.436163
17	RTS	.30	.32	.28	1.378988
18	BMH	8.42	8.84	8.00	1.279048
19	POH	13467.00	14140.35	12793.65	1.036075
20	DRCT	1.80	1.89	1.71	1.036075
21	MTBD	2035.80	2137.59	1934.01	1.036075
22	PAMH	.50	.52	.47	.253212
23	BMC	6.30	6.62	5.99	.099940
24	PA	1.00	1.05	.95	.079005
25	SA	2.55	2.68	2.42	.017115
26	BCMH	.00	.00	.00	.000000
27	PCB	.00	.00	.00	.000000
28	OST	.70	.74	.66	.000000
29	SYSI	.00	.00	.00	.000000
30	SEC	.00	.00	.00	.000000
31	BRCT	4.00	4.20	3.80	.000000
32	DEVC	.00	.00	.00	.000000
33	SMI	.00	.00	.00	.000000
34	IMC	.00	.00	.00	.000000
35	SMH	.00	.00	.00	.000000

17:55:10 07-15-89

Life Cycle Cost Sensitivity Analysis

File Name: newrst

Work Unit Code Name: WHEEL,MLG
Work Unit Code: NONE
Manufacturer: BENDIX PROPOSAL
National Stock Number: NONE AVAILABLE
Data gathered by: CAPT DAVID MARTIN
File Time and Date: 15:49:15 06-30-89

Variables Changed by Delta = .05
Confidence Level of Base and Depot Spares = .95

Rank	Variable	Original Value	Upper	Lower	Sensitivity
1	PIUP	20.00	21.00	19.00	121.886300
2	MTBR	1002.00	1052.10	951.90	116.749700
3	AOH	115644.00	121426.20	109861.80	116.471500
4	NRTS	.70	.74	.66	107.010100
5	PSC	3.00	3.15	2.85	68.165830
6	W	160.60	168.63	152.57	68.165720
7	DMC	743.00	780.15	705.85	27.518570
8	SYSI	846500.00	888825.00	804175.00	19.403490
9	UC	7800.00	8190.00	7410.00	9.654753
10	DLR	21.46	22.53	20.39	9.537736
11	DMH	12.00	12.60	11.40	9.537736
12	BLR	9.57	10.05	9.09	5.785517
13	RMC	230.50	242.02	218.98	5.389195
14	COND	.01	.01	.01	5.363751
15	PP	49.00	51.45	46.55	5.177854
16	RMH	8.40	8.82	7.98	4.253294
17	M	11.00	11.55	10.45	3.959090
18	POH	13467.00	14140.35	12793.65	1.787917
19	DRCT	1.80	1.89	1.71	1.787917
20	MTBD	4071.00	4274.55	3867.45	1.787917
21	RTS	.30	.32	.28	1.378988
22	BMH	8.42	8.84	8.00	1.279048
23	PAMH	.50	.52	.47	.253174
24	PA	1.00	1.05	.95	.118507
25	BMC	6.30	6.62	5.99	.099940
26	SA	2.55	2.68	2.42	.025673
27	PCB	.00	.00	.00	.000000
28	OST	.70	.74	.55	.000000
29	DEVC	.00	.00	.00	.000000
30	BRCT	4.00	4.20	3.80	.000000
31	SMI	.00	.00	.00	.000000
32	SMH	.00	.00	.00	.000000
33	BCMH	.00	.00	.00	.000000
34	IMC	.00	.00	.00	.000000
35	SEC	.00	.00	.00	.000000

Appendix I: Initial Inputs for C-141A/B CSD Alternative

COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0

==

LIST INPUTS PROGRAM

DEFENSE SYSTEMS
MANAGEMENT COLLEGE

INPUT LCC DATA FILE: c141csd.dat 07-15-89

Level 1 = ORGANIZATIONAL
Level 2 = INTERMEDIATE
Level 3 = DEPOT

NOTE: Numbers in parentheses following section headings denote references from CASA Users Manual

STUDY NAME (4.1): C-141 Constant Speed Drive

GENERAL INPUT INFORMATION (4.2)

Reliability Growth Option:	N (None)
Initial Year of Study:	1985
Year in Which Dollars are Expressed:	1985
Study Life (Months):	300
Cost Adjustment Factor:	1.000
MTBF Adjustment (Degradation) Factor:	1.000
Average Operating Hours per Month per System:	83.83
System Operator Required Portion:	.00000
System Operator Labor Rate ($/hr):	.00
Support Equipment and Spares Factor:	1.000
Portion of Repair Time Spent on RTOK:	.000
Consumables Cost as Portion of Piece Parts Cost:	.000

MAINTENANCE LEVEL INFORMATION (4.3)

	Level 1	Level 2	Level 3
No. of Operating Systems per Loc.:	108.	0.	1084.
Maintenance Labor Rate ($/hr):	9.57	.00	21.46
Available Support Equip. Hours per Mo.:	173.	173.	173.
Support Equipment Utilization Factor:	1.00	1.00	1.00
Initial Spt Eq Spares Cost Portion:	.95	95	.95
Spares Confidence Level:	.95	.95	.95
Earned Hour Ratio:	1.00	1.00	1.00
System Repair Elapsed Time (Hours):	16 00	.00	48 00

SYSTEM PRODUCTION AND COST DATA (4.4)

Previous Quantity of Systems Produced:	2007.
Base Unit Cost per System ($):	60133.76
Installation Cost per System ($):	.00

Year	Quantity Produced	Quantity Slope	Rate Slope
1985	0.	1.0000	1.0000

SYSTEM DEPLOYMENT DATA (4.5)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	1084.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

SYSTEM HARDWARE DATA (4.11)

List of Abbreviations:

COND :	Portion of failures expected to be condemned
DPT :	Depot level
INT :	Intermediate level
K :	Adjustment (Degradation) factor for MTBF
LREM :	Primary Removal Level
LRPR :	Primary Repair Level
MCPR :	Material cost per repair
MTBF :	Mean time between failures
MTTR :	Mean time to repair
NRTS :	Portion of failures not repairable at the primary repair level
ORG :	Organizational Level
QPNHA:	Quantity per next higher assembly
RTOK :	Portion of failures expected to retest okay
TAT :	Turnaround time in months

1) No.	Item Name	Type	Unit Cost	QPNHA	MTBF	K	MTTR
1) 1	Contant Speed Drive	1	60133.76	1	1595.	1.000	16.00
1) 2		2	.00	1	1.	1.000	.00
1) 3		3	00	1	1.	1.000	.00

2) Weight (Lb.	Spares TAT ORG	Spares TAT INT	Spares TAT DPT	LRPR	LREM	RTOK	MCPR	NRTS	NRTS TAT	COND	COND TAT
2) 75.00	.03	.00	1.05	3	1	.001	2683.24	.790	1.05	.000	.00
2) .00	.00	.00	.00	2	1	.000	.00	.000	.00	.000	.00
2) .00	.00	.00	.00	3	2	.000	.00	.000	.00	.000	.00

MISCELLANEOUS OPERATION AND SUPPORT COSTS (4.30)

Name	Level	Year	Cost
Annual Gen. Repairs	3	1985	489000.00
		1986	489000.00
		1987	489000.00
		1988	489000.00
		1989	489000.00
		1990	489000.00
		1991	489000.00
		1992	489000.00
		1993	489000.00
		1994	489000.00
		1995	489000.00
		1996	489000.00
		1997	489000.00
		1998	489000.00
		1999	489000.00
		2000	489000.00
		2001	489000.00
		2002	489000.00
		2003	489000.00
		2004	489000.00
		2005	489000.00
		2006	489000.00
		2007	489000.00
		2008	489000.00
		2009	489000.00

TRANSPORTATION COST DATA (4.16)

Cost ($) per Pound Between:

Organizational and Intermediate Levels:	.000
Organizational and Depot Levels:	3.000
Intermediate and Depot Levels:	.000
Depot Level and a Factory Depot:	.000

Paperwork and Packaging Cost per Trip: .000

Appendix J: Initial Inputs for C-141A/B VSCF Alternative

COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0
==

LIST INPUTS PROGRAM

DEFENSE SYSTEMS
MANAGEMENT COLLEGE

INPUT LCC DATA FILE: c141vscf.dat 07-15-89

Level 1 = ORGANIZATIONAL
Level 2 = INTERMEDIATE
Level 3 = DEPOT

NOTE: Numbers in parentheses following section headings denote references from CASA Users Manual

STUDY NAME (4.1): C141 Variable Speed Constant Frequency Drive

GENERAL INPUT INFORMATION (4.2)

Reliability Growth Option:	N (None)
Initial Year of Study:	1985
Year in Which Dollars are Expressed:	1985
Study Life (Months):	300
Cost Adjustment Factor:	1.000
MTBF Adjustment (Degradation) Factor:	1.000
Average Operating Hours per Month per System:	83.83
System Operator Required Portion:	.00000
System Operator Labor Rate ($/hr):	.00
Support Equipment and Spares Factor:	1.000
Portion of Repair Time Spent on RTOK:	.000
Consumables Cost as Portion of Piece Parts Cost:	.000

MAINTENANCE LEVEL INFORMATION (4.3)

	Level 1	Level 2	Level 3
No. of Operating Systems per Loc.:	108.	0.	1084.
Maintenance Labor Rate ($/hr):	9.57	.00	21.46
Available Support Equip. Hours per Mo.:	173.	173.	173.
Support Equipment Utilization Factor:	1.00	1.00	1.00
Initial Spt Eq Spares Cost Portion:	.95	.95	.95
Spares Confidence Level:	.95	.95	.95
Earned Hour Ratio:	1.00	1.00	1.00
System Repair Elapsed Time (Hours):	16.00	.00	48.00

SYSTEM PRODUCTION AND COST DATA (4.4)

Previous Quantity of Systems Produced:	0.
Base Unit Cost per System ($):	75400.00
Installation Cost per System ($):	15000.00

Year	Quantity Produced	Quantity Slope	Rate Slope
1985	1435.	1.0000	1.0000

SYSTEM DEPLOYMENT DATA (4.5)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	1084.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

SYSTEM HARDWARE DATA (4.11)

List of Abbreviations:

- COND : Portion of failures expected to be condemned
- DPT : Depot level
- INT : Intermediate level
- K : Adjustment (Degradation) factor for MTBF
- LREM : Primary Removal Level
- LRPR : Primary Repair Level
- MCPR : Material cost per repair
- MTBF : Mean time between failures
- MTTR : Mean time to repair
- NRTS : Portion of failures not repairable at the primary repair level
- ORG : Organizational Level
- QPNHA: Quantity per next higher assembly
- RTOK : Portion of failures expected to retest okay
- TAT : Turnaround time in months

1)	No.	Item Name	Type	Unit Cost	QPNHA	MTBF	K	MTTR				
2)	Weight (Lbs)	---Spares TAT--- ORG	INT	DPT	LRPR	LREM	RTOK	MCPR	NRTS	NRTS TAT	COND	COND TAT
1)	1	Var Spd Cnt Freq Dr	1	74500.00	1	4000.	1.000	16.00				
2)	75.00	.03	.00	1.05	3	1	.001	1969.92	.790	1.05	.000	.00
1)	2		2	.00	1	1.	1.000	.00				
2)	.00	.00	.00	.00	2	1	.000	.00	.000	.00	.000	.00
1)	3		3	.00	1	1.	1.000	.00				
2)	.00	.00	.00	.00	3	2	.000	.00	.000	.00	.000	.00

PRE-PRODUCTION NON-RECURRING ENGINEERING COSTS (4.9)

Name	Year	Cost
Airframe Non-Recurr	1985	1600000.00

MISCELLANEOUS ACQUISITION COSTS (4.29)

Name	Year	Cost
PRAM Cst/Cont Nonrec	1985	7000000.00

TRANSPORTATION COST DATA (4.16)

Cost ($) per Pound Between:	
Organizational and Intermediate Levels:	.000
Organizational and Depot Levels:	3.000
Intermediate and Depot Levels:	.000
Depot Level and a Factory Depot:	.000
Paperwork and Packaging Cost per Trip:	.000

Appendix K: Initial Inputs for AN/ALR-46/69 Existing Power Supply Alternative

COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0

****

LIST INPUTS PROGRAM

DEFENSE SYSTEMS
MANAGEMENT COLLEGE

INPUT LCC DATA FILE: exist46.dat　　　　07-22-89

Level 1 = ORGANIZATIONAL
Level 2 = INTERMEDIATE
Level 3 = DEPOT

NOTE: Numbers in parentheses following section headings denote references from CASA Users Manual

STUDY NAME (4.1): Existing AN/ALR-46/69 Power Supply

GENERAL INPUT INFORMATION (4.2)

Reliability Growth Option:	N (None)
Initial Year of Study:	1985
Year in Which Dollars are Expressed:	1985
Study Life (Months):	120
Cost Adjustment Factor:	1.000
MTBF Adjustment (Degradation) Factor:	1.000
Average Operating Hours per Month per System:	26.34
System Operator Required Portion:	.00000
System Operator Labor Rate ($/hr):	.00
Support Equipment and Spares Factor:	1.000
Portion of Repair Time Spent on RTOK:	.000
Consumables Cost as Portion of Piece Parts Cost:	.010

MAINTENANCE LEVEL INFORMATION (4.3)

	Level 1	Level 2	Level 3
No. of Operating Systems per Loc.:	25.	0.	3319.
Maintenance Labor Rate ($/hr):	9.57	.00	46.32
Available Support Equip. Hours per Mo.:	173.	173.	173.
Support Equipment Utilization Factor:	1.00	1.00	1.00
Initial Spt Eq Spares Cost Portion:	.95	.10	.95
Spares Confidence Level:	.95	.95	.95
Earned Hour Ratio:	1.00	1.00	1.00
System Repair Elapsed Time (Hours):	6.65	72.00	11.18

SYSTEM PRODUCTION AND COST DATA (4.4)

Previous Quantity of Systems Produced.	3765.
Base Unit Cost per System ($).	4160.00
Installation Cost per System ($):	.00

PRE-PRODUCTION NON-RECURRING ENGINEERING COSTS (4.9)

Name	Year	Cost
PRAM PROJECT COST	0	600000.00

SYSTEM HARDWARE DATA (4.11)

List of Abbreviations:

COND : Portion of failures expected to be condemned
DPT : Depot level
INT : Intermediate level
K : Adjustment (Degradation) factor for MTBF
LREM : Primary Removal Level
LRPR : Primary Repair Level
MCPR : Material cost per repair
MTBF : Mean time between failures
MTTR : Mean time to repair
NRTS : Portion of failures not repairable at the primary repair level
ORG : Organizational Level
QPNHA: Quantity per next higher assembly
RTOK : Portion of failures expected to retest okay
TAT : Turnaround time in months

1)	No.	Item Name	Type	Unit Cost	QPNHA	MTBF	K	MTTR				
2)	Weight (Lbs)	---Spares TAT--- ORG	INT	DPT	LRPR	LREM	RTOK	MCPR	NRTS	NRTS TAT	COND	COND TAT
1)	1	ALR-46/69 Power Sup	1	3000.00	1	10000.	1.000	1.50				
2)	5.00	.10	.00	.91	3	1	.000	78.00	.895	.90	.000	.00
1)	2		2	.00	1	1.	1.000	.00				
2)	.00	.00	.00	.00	2	1	.000	.00	.000	.00	.000	.00
1)	3		3	.00	1	1.	1.000	.00				
2)	.00	.00	.00	.00	3	2	.000	.00	.000	.00	.000	.00

SYSTEM DEPLOYMENT DATA (4.5)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	3319.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TRANSPORTATION COST DATA (4.16)

Cost ($) per Pound Between:

Organizational and Intermediate Levels:	.000
Organizational and Depot Levels:	4.080
Intermediate and Depot Levels:	.000
Depot Level and a Factory Depot:	.000

Paperwork and Packaging Cost per Trip: .000

Appendix L: Initial Inputs for AN/ALR-46/69 Improved Power Supply Alternative

COST ANALYSIS AND STRATEGY ASSESSMENT (CASA) MODEL--VERSION 1.0

::

LIST INPUTS PROGRAM

DEFENSE SYSTEMS
MANAGEMENT COLLEGE

INPUT LCC DATA FILE: new46.dat 07-24-89

Level 1 = ORGANIZATIONAL
Level 2 = INTERMEDIATE
Level 3 = DEPOT

NOTE: Numbers in parentheses following section headings denote references from CASA Users Manual

STUDY NAME (4.1): Improved AN/ALR-46/69 Power Supply

GENERAL INPUT INFORMATION (4.2)

Reliability Growth Option:	N (None)
Initial Year of Study:	1985
Year in Which Dollars are Expressed:	1985
Study Life (Months):	120
Cost Adjustment Factor:	1.000
MTBF Adjustment (Degradation) Factor:	1.000
Average Operating Hours per Month per System:	26.34
System Operator Required Portion:	.00000
System Operator Labor Rate ($/hr):	.00
Support Equipment and Spares Factor:	1.000
Portion of Repair Time Spent on RTOK:	.000
Consumables Cost as Portion of Piece Parts Cost:	.010

MAINTENANCE LEVEL INFORMATION (4.3)

	Level 1	Level 2	Level 3
No. of Operating Systems per Loc.:	25.	0.	3319.
Maintenance Labor Rate ($/hr):	9.57	35.00	46.32
Available Support Equip. Hours per Mo.:	173.	173.	173.
Support Equipment Utilization Factor:	1.00	1.00	1.00
Initial Spt Eq Spares Cost Portion:	.95	.10	.95
Spares Confidence Level:	.95	.95	.95
Earned Hour Ratio:	1.00	1.00	1.00
System Repair Elapsed Time (Hours):	6.65	72.00	1.30

SYSTEM PRODUCTION AND COST DATA (4.4)

Previous Quantity of Systems Produced:	3765.
Base Unit Cost per System ($):	3000.00
Installation Cost per System ($).	.00

SYSTEM DEPLOYMENT DATA (4.5)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985	3319.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0

SYSTEM HARDWARE DATA (4.11)

List of Abbreviations:

COND : Portion of failures expected to be condemned
DPT : Depot level
INT : Intermediate level
K : Adjustment (Degradation) factor for MTBF
LREM : Primary Removal Level
LRPR : Primary Repair Level
MCPR : Material cost per repair
MTBF : Mean time between failures
MTTR : Mean time to repair
NRTS : Portion of failures not repairable at the primary repair level
ORG : Organizational Level
QPNHA: Quantity per next higher assembly
RTOK : Portion of failures expected to retest okay
TAT : Turnaround time in months

1)	No.	Item Name	Type	Unit Cost	QPNHA	MTBF	K	MTTR
1)	1	ALR-46/69 Power Sup	1	4160.00	1	2960.	1.000	11.18
1)	2		2	.00	1	1.	1.000	.00
1)	3		3	.00	1	1.	1.000	.00

2)	Weight (Lbs)	---Spares TAT--- ORG	INT	DPT	LRPR	LREM	RTOK	MCPR	NRTS	NRTS TAT	COND	COND TAT
2)	5.00	.10	.00	.91	3	1	.000	78.00	.895	.90	.000	.00
2)	.00	.00	.00	.00	2	1	.000	.00	.000	.00	.000	.00
2)	.00	.00	.00	.00	3	2	.000	.00	.000	.00	.000	.00

TRANSPORTATION COST DATA (4.16)

Cost ($) per Pound Between:

Organizational and Intermediate Levels:	.000
Organizational and Depot Levels:	4.080
Intermediate and Depot Levels:	.000
Depot Level and a Factory Depot:	.000

Paperwork and Packaging Cost per Trip: .000

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Thesis Chairman: Robert D. Materna, Lieutenant Colonel, USAF
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The purpose of this research was to demostrate how microcomputer-based logistics models could be used to enhance the analysis of major project proposals for the USAF Productivity, Reliability, Availability, and Maintainability (PRAM) Program Office. The study starts by reviewing technology insertion, focusing on the Air Force process. The evolution of the USAF PRAM Program Office is discussed, and the process that PRAM uses to assess technology is addressed. Finally, the evolution of computer-based logistics support models is reviewed, focusing on the capabilities that current models offer the supportability analyst.

Three PRAM projects were selected for analysis. The projects represented "typical" PRAM projects. A structured approach was taken to determine the decision orientation and data available for each project.

A model survey was made to identify models that might have capabilities matching the level of analysis required for each project. The informal survey identified the need for a greater amount of data for model use. During this additional data gathering process, data quality issues surfaced, indicating the need for models with strong sensitivity analysis capabilities. After all additional data was collected, final model selection was made, and analyses were performed using two models, the Statistically Improved Life Cycle Cost (SILCC) and Cost Analysis and Strategy Assessment (CASA) models.

This research demonstrated that more thorough economic analysis was possible using logistics models. In two of the projects analyzed, the findings revealed the original PRAM analysis had overestimated the cost savings of the proposed improvement. Additionally, models were used to perform detailed sensitivity analysis, thereby mitigating the effects of data uncertainty. The thesis concludes by recommending further work toward improving data quality, developing a standardized PRAM data collection process, accomplishing PRAM modeling implementation assessment, and coducting research into the feasibility of adapting the tailored modeling approach in other logistics support agencies.

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